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WITH PLATE I.

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AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XII. — *On Rowland's new Method for measuring Electric Absorption, and Losses of Energy due to Hysteresis and Foucault Currents, and on the Detection of short Circuits in Coils;* by LOUIS M. POTTS.

THE following investigation has had as its object the testing of methods devised by Professor Rowland* for the measurement, in the first place, of electric absorption; further, of the energy losses due to hysteresis and Foucault currents; and, finally, for the detection of short circuits in coils.

I. ELECTRIC ABSORPTION.

Historical.—It has long been known that a Leyden jar, which has been charged and then discharged, will show another charge after standing a short time. If this is discharged, after a short time the jar will show another charge; this may be repeated indefinitely. These "after-charges" are known as residual charges and are due to the phenomenon now called electric absorption. Faraday† made some experiments on this phenomenon in Leyden jars, and seems to have attributed it to a conduction of the charge into the interior of the dielectric, and after discharge creeping back again to the coatings and manifesting itself as the residual charge. Kohlrausch‡ was the first to make any elaborate investigation of the subject. He charged the condenser and then measured the potential at certain intervals with an electrometer. In this way he obtained the relation between the potential and time. He advanced the idea that the phenomenon was due to an electric polarity of

* See this Journal for July, 1899, pp. 35–57.

† Faraday, Experimental Researches.

‡ Pogg. Annalen, vol. xci, pp. 59–82, 179–214.

the particles of the dielectric, produced by the electric force between the plates of the condenser. Rowland and Nichols* have shown that certain homogeneous crystals show no electric absorption. H. Hertz† has shown that pure benzine possesses no electric absorption, while impure does.‡ The great sensitiveness of this phenomenon to change of temperature has been noted. The energy loss in condensers due to it has also been studied.§

Theory of Electric Absorption.

The theory of electric absorption has been developed by Clausius,‖ Riemann,¶ Maxwell** and Rowland.†† The following development is that of Maxwell applied by Prof. Rowland to the case of a dielectric acted upon by an e m.f. varying harmonically.

A dielectric such as paraffin paper is made of a substance of a certain dielectric capacity and specific resistance having imbedded in it particles of a different dielectric capacity and different specific resistance. Now we can very closely approximate to this case by considering a plane plate condenser, in which the dielectric is made up of a number of layers of different substances. An ordinary condenser is merely a great number of very small condensers like this, joined in multiple.

The theory of electric absorption as extended by Prof. Rowland shows that a condenser possessing electric absorption should act as a capacity in series with a certain resistance. The value of each depends on the period of the current. If b_1, b_2, etc., are constants and T the period of the current, the resistance is of the form

$$R = b_1 T^2 - b_2 T^4 + b_3 T^6, \text{ etc.}$$

and if a_1, a_2, etc., are constants the capacity is of the form

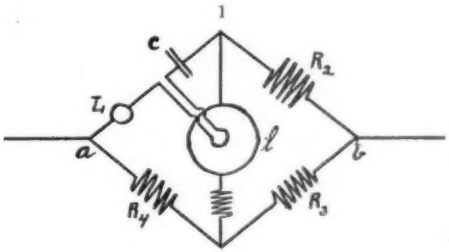
$$\frac{1}{c} = a_1 - a_2 T^2 + d_2 T^4, \text{ etc.}$$

General Theory.—The arrangement adopted is essentially a Wheatstone bridge, in which the fixed coils of an electro-dynamometer were placed in one arm of the bridge and the hang-

* Phil. Mag., p. 414, 1881.
† Wied. Annalen, p. 281, 1883.
‡ Phil. Trans., p. 599, 167; Proc. Roy. Soc., p. 468, 1875.
§ Physical Review, 1899, p. 79.
‖ Théorie Méchanique de la Chaleur; deuxième partie.
¶ Riemann, Mathematische Werke, p. 48.
** Electr. and Mag., vol. i, p. 452. †† This Journal, Dec. 1897, p. 429.

ing coil in the cross-connection, in place of the galvanometer in the direct-current method of use. The adjustment of the bridge thus used depends upon the fact that there will be no deflection of the electro-dynamometer if the phase difference of the current in the fixed coils and those in the hanging coil is 90°.

Fig. 1 is the arrangement used. Let R_1, R_2, R_3 and R_4 be the resistances of the different arms and r that of the cross-connection. Let Cn be the current in the arm n of the bridge, and C_5 in the cross-connection.



If we apply at a and b a direct electromotive force E, we shall have the following expressions for the currents:

$$C'_5 = E\frac{R_2R_4 - R_3R_1}{\Delta} \qquad (1)$$

$$C'_1 = E\frac{R_4(R_2+R_3)+r(R_3+R_4)}{\Delta} \qquad (2)$$

where

$$\Delta = r(R_3+R_4)(R_1+R_2)+R_1R_2(R_3+R_4)+R_3R_4(R_1+R_2)$$

If in place of using a direct current we apply to the terminals a, b, a simple alternating e.m.f. Ee^{ibt}, we shall get the corresponding quantities by the following substitutions:

$$C'_1 = C_1e^{i(bt+\phi_1)} \qquad C'_5 = C_5e^{i(bt+\phi_5)}$$

and if we place in the arm 1 a coil of self-induction L and a capacity c, we must substitute for R_1, R'_1, where

$$R'_1 = R_1 + ibL - \frac{i}{bc}$$

and, if l is the self-induction of the hanging coils of the electro-dynamometer, we must replace r by r', where

$$r' = r + ibl$$

Making these substitutions and dividing (1) by (2), we have

$$\frac{C_2}{C_1}\epsilon^{i(\phi_2-\phi_1)} = \frac{R_2R_4-R_1R_3-i\left(bL-\frac{1}{bc}\right)R_3}{R_4(R_2+R_3)+r(R_3+R_4)+ibl(R_3+R_4)} \qquad (3)$$

Now taking only the real part of the above quantities we have

$$\frac{C_2}{C_1}\cos\phi =$$

$$\frac{(R_2R_4-R_1R_3)\{R_4(R_2+R_3)+r(R_3+R_4)\}+\left(\frac{l}{c}-b^2lL\right)R_3(R_3+R_4)}{\{R_4(R_2+R_3)+r(R_3+R_4)\}^2+b^2l^2(R_3+R_4)^2} \qquad (4)$$

If $\phi=90°$, $\cos\phi=0$ or

$$(R_2R_4-R_1R_3)\{R_4(R_2+R_3)+r(R_3+R_4)\}+\left(\frac{l}{c}-b^2lL\right)R_3(R_3+R_4)=0$$

$$\text{or} \qquad R_1=\frac{R_2R_4}{R_3}+\left(\frac{l}{c}-b^2lL\right)\frac{R_3+R_4}{R_4(R_2+R_3)+r(R_3+R_4)} \qquad (5)$$

This then is the condition satisfied when there is no deflection of the electro-dynamometer.

The first term of the above is the same as the expression for R_1, when the adjustment is conditioned by no deflection of a galvanometer in the cross-connection, and a direct current is used. The second is a correction term, always very small, at most one per cent and often entirely negligible. In a circuit carrying an alternating current the effective values of R_1, etc., are not usually the same as their actual ohmic values, but are larger. They include that part of the impedance against which work must be done to maintain the current. Let R_2, R_3 and R_4 be as nearly as possible pure ohmic resistances, i. e. let their actual values be equal to their effective ones. And let the arm 1 contain iron, a condenser possessing electric absorption, or any piece of apparatus using energy which is not expended in heating the conductors of that arm. The value of R_1 calculated by the above formula will be the effective resistance, and this, less the actual value as measured by a direct current, will be the increased resistance due to the hysteresis of the iron, the energy-loss by electric absorption, etc.

In the measurement of certain quantities (*e. g.* hysteresis loss in iron) by this method, it is necessary to insert in arm 1 of the bridge a large coil. Such a coil acts not as a pure self-induction, but on account of the numerous turns of the wire so close to one another as a self-induction in *multiple* with a

capacity. On this account formula (5) is not strictly accurate but should include a term involving the capacity of the coil. Let the capacity which in parallel with the self-induction, L, will have the same effect as the given coil be k and let R'_1 be the resistance of the coil and R''_1 the resistance of the remainder of arm 1. Substitute in (3) in place of

$$R_1 + ib\mathrm{L} - \frac{i}{bc}$$

$$R''_1 + \frac{R'_1 + ib\mathrm{L}}{(1-b^2k\mathrm{L}) + ibkR'_1}$$

and also put

$$R_4(R_3+R_2)+r(R_4+R_3)=\mathrm{A}$$

Then

$$\frac{C_3}{C_1}\,\varepsilon^{i(\phi_3-\phi_1)} =$$

$$\frac{(R_3R''_1-R_2R_4)(1-b^2k\mathrm{L})+R'_1R_3+i\{bkR'_1R''_1R_3+b\mathrm{L}R_3-\dfrac{bkR_1R_2R_4}{bl(R_3+R_4)}\}}{\mathrm{A}(1-b^2k\mathrm{L})-b^2klR'_1(R_3+R_4)+i\{\mathrm{A}bkR'_1+(1-b^2k\mathrm{L})\}} \quad (6)$$

As before, the condition for no deflection is that the real part of (6) vanish, or

$$[(R_2R_4-R_3R''_1)(1-b^2k\mathrm{L})-R'_1R_3][\mathrm{A}(1-b^2k\mathrm{L})-b^2klR'_1(R_3+R_4)]$$
$$=[\mathrm{A}bkR'_1+(1-b^2k\mathrm{L})bl(R_3+R_4)][b\mathrm{L}R_3-bkR'_1(R_2R_4-R_3R''_1)]$$

Expanding this it becomes,

$$\mathrm{A}(1-b^2k\mathrm{L})^2(R_2R_4-R_3R''_1)-\mathrm{A}R'_1R_3(1-b^2k\mathrm{L})$$
$$+b^2klR'^2_1(R_3+R_4)R_3-(R_2R_4-R_3R''_1)(1-b^2k\mathrm{L})b^2klR'_1$$
$$(R_3+R_4)=\mathrm{A}b^2k\mathrm{L}R'_1R_3-\mathrm{A}b^2k^2R'^2_1(R_2R_4-R''_1R_3)$$
$$(1-b^2k\mathrm{L})(R_3+R_4)R_3b^2l\mathrm{L}-(1-b^2k\mathrm{L})(R_3+R_4)(R_2R_4-R''_1R_3)$$
$$b^2klR'_1$$

Now since k is in all cases small and l is also small, the terms above which involve k^2 and kl may be dropped, whence we get,

$$R_1=\frac{\mathrm{A}(1-b^2k\mathrm{L})^2(R_2R_4-R_3R''_1)-b^2l\mathrm{L}(R_3+R_4)R_3(1-b^2k\mathrm{L})}{\mathrm{A}R_3}$$

$$=(1-b^2c\mathrm{L})^2\frac{R_2R_4-R_3R''_1}{R_3}-b^2l\mathrm{L}\frac{R_3+R_4}{\mathrm{A}}(1-b^2k\mathrm{L})$$

Now since the last term is very small and $1-b^2k\mathrm{L}$ is nearly 1, it may be dropped; and we have for the final formula,

$$R'_1=\frac{R_2R_4-R_3R''_1}{R_3}+\left(\frac{l}{c}-b^2l\mathrm{L}\right)\frac{R_3+R_4}{R_4(R_3+R_2)+r(R_3+R_4)}$$
$$-2b^2k\mathrm{L}\frac{R_2R_4-R_3R''_1}{R_3} \quad (7)$$

In the measurement of electric absorption and hysteresis loss, it is necessary to know the period of the current used. In this investigation a speed counter and chronograph were used; the speed counter was placed at the end of the dynamo shaft, and directly connected to it, a contact was so arranged that for every one hundred revolutions of the dynamo armature a circuit was closed and a record made on a chronograph sheet. On a table beside the electro-dynamometer was a key, which also could be used to make a record on the chronograph sheet. As soon as the bridge had been balanced, this key was pressed. And by the measurement of this sheet the period of the current at the time of the observations was quite accurately determined. The error from this source was usually not more than one part in 1000, never more than 1 in 100.

After each adjustment, the resistance of each arm was determined by the use of a "Post-office Box" (when the current through any part of the apparatus was not large, it was not necessary to measure its resistance after each adjustment). The resistance of that part which was affected the most by heating was measured first, and in this way the actual value at the time of adjustment was quite closely determined. In cases where the heating was large, the error from this cause might reach several parts in 1000 in R'_1, and consequently a considerably greater amount in the value of the electric absorption resistance.

Errors due to induction and electrostatic action of the different portions of the apparatus were carefully guarded against by the arrangement. And induction was tested for by reversal of the relative directions of the currents in different portions of the apparatus. Usually no effect was noticed or at most it was very small. The errors introduced by the self-induction of the electro-dynamometer coils and also that caused by the electrostatic action of the turns of a large coil on one another, were determined and corrected for when sufficiently large in amount.

Apparatus.

*Electro-dynamometer.**—The self-induction of the fixed coils was ·0165 henry, and of the hanging coil ·0007 henry.

Dynamos.—The current used in this investigation was furnished by one of three dynamos. The Westinghouse alternator in power house of the University furnished a current of period ·0075, i. e. 133 complete periods per sec. This was used for only a few observations. In most of the work two small dynamos constructed in the University workshop were

*See this Journal, July, 1897, p. 35.

employed. Both were directly connected to small electric motors. Both had armatures of the pancake type. The one had four coils in the armature and four poles and thus produced a current of two complete periods for each revolution of the armature. The other was larger but of similar construction, having six coils in the armature and six poles, and gave three complete periods for one revolution. If the load on the dynamo was not changed, these dynamos would run at a very nearly constant speed. With the second dynamo, the number of complete periods per second could be varied from 6 to 70. However, at the lower speed the electro-dynamometer was difficult to balance, since the hanging coil would vibrate with the current and blurr the image of the scale. The voltage furnished could be controlled very well by changing the strength of the field. In any one series of observations the same dynamo was used, as the results using different dynamos would not be comparable, on account of the different harmonics introduced. The small dynamos which were almost exclusively used gave, however, very good sine curves.

Resistances.—The high resistances and those which were required to carry very small currents were made of fine german-silver wire wound on thin sheets of fiber. The self-induction and electrostatic action of these was practically zero. The lower resistances, and those required to carry larger currents were made of a special resistance wire, which had a very slight negative temperature coefficient, and would bear considerable heating with a very small change of resistance. This wire was wound on slates. Each slate contained sufficient number 30 wire to have nearly 2000 ohms resistance. These were conveniently subdivided for adjustment. For the final adjustment an ordinary resistance box was used, but never more than fifty ohms were used in this box, and then the total resistance of that arm was at least 1000 ohms.

Self-inductance.—Two coils were used.

A. External diameter 35·46^{cm}; internal diameter 23·8^{cm}, 3700 turns No. 20 B. and S. Self-inductance 5·30 henrys. Resistance 188 ohms.

C. Same dimensions as A except depth. Self-inductance 1·30 henrys, 1747 turns No. 22 B. and S., single cotton covered copper wire. Resistance about 78 ohms.

Condensers.—2 and 3. Paper condensers made by Marshall of 2 and 3 micro-farads capacity.

Willyoung.—8 micro-farad wax condenser, made by Willyoung & Co. and divided into sections of one micro-farad each.

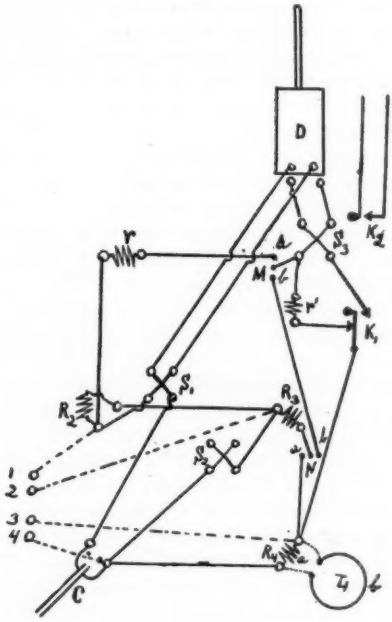
Mica condensers.—$\frac{1}{8}$ M. F. standard condenser made by Elliot Bros.

$\frac{1}{3}$ M. F. standard condenser made by the Troy Electric Co.

The Bridge.—The bridge was set up permanently on a table; all connections were soldered; and the wires used in connecting different parts of the bridge and instruments were No. 25 cotton-covered copper wire. All wires were made as short as possible and no wires were twisted.

Investigation.—In fig. 2, is shown the arrangement used in the measurement of electric absorption; s_1, s_2 and s_3 are current

2



reversing switches, which were used in testing for induction of one part of the bridge on another. In most cases, however, there was no appreciable error due to this cause, so that it was not usually necessary to take a set of readings for all positions of these switches. M and N are two switches which were used in a later experiment described below. In the measurement of electric absorption M and N were in the position *a*. In the fourth arm of the bridge there was a resistance R_4. K_1 is a key to close the circuit through the hanging coil of the electro dynamometer. When K_1 was not pressed down, it closed the cross-connection of the bridge through a resistance

r' equal to the resistance of the hanging coil of the electrodynamometer. This avoided any sudden change of current and hence a change of speed of dynamo. The key R_2 was the chronograph key described above and was closed just at the time the bridge was balanced.

TABLE I.

$T = \cdot0075 \qquad r = 6535$

Condenser.	R_1	R_2	R_3	R_4	Calculated R'_1	A $R'_1 - R_1$
3	34·04	2022	4600	99·7	43·86	9·82
3	34·45	2020	9090	203·4	45·22	10·77
2	34·45	2020	2475	99·7	81·46	47·01
2, 3[S] ...	34·45	2020	8920	407·0	92·23	57·78
2, 3[P] ...	34·45	2020	2205	51·7	47·37	12·92
2, 3[P] ...	34·48	1991	4130	99·7	48·09	13·61
2, 3[S] ...	34·19	1992	2031	99·6	97·83	63·64
3	34·45	1992	3325	99·6	59·72	25·27
2	34·49	1992	2414	99·6	82·28	47·79

A few measurements were first made using the paper condensers 2 and 3. Table I shows the results. In this and the following tables, R'_1 denotes the effective value of R_1 calculated by formula (5) and $A(=R_1^1 - R_1)$ the resistance due to the electric absorption. T is the period of the current. The

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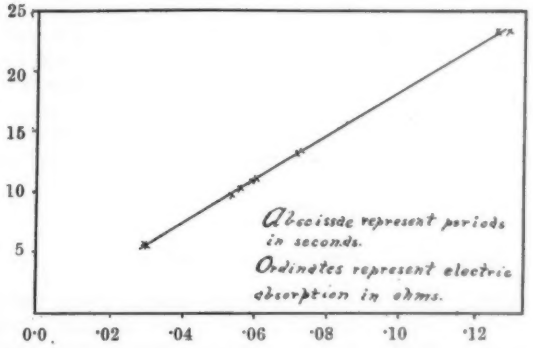

results with these condensers was very unsatisfactory, as the heating was so great that it was difficult to make accurate determinations.

The wax condenser made by Willyoung was next used. This condenser had been made in a vacuum under pressure, and showed quite small heating by the current. By taking a series of measurements during an afternoon, the results were not affected to any great extent by the changes in temperature

of the room, as these were comparatively slow. Of course there was still some slight heating by the current; but this in extreme cases did not amount to enough to occasion an error of more than one or two per cent.

Table II gives results for the absorption of all eight sections of this condenser in parallel, for different periods of the current. In Fig. 3 the above results are plotted; the ordinates

TABLE II.

Date, etc.		r=6020 R_2	R_1	R_2=1060 Calculated. R_1'	A $(R_1'-R_1$	R_4=303·1 T.	$\frac{A}{T}$
2–23–99	1	7192	34·68	44·81	10·13	·0557	181·7
–22–	2	7251	34·70	44·45	9·75	·0544	179·2
	3	5564	34·67	57·91	23·24	·1269	183·2
	4	5556	34·66	58·00	23·34	·1291	180·8
	5	6694	34·73	48·15	13·42	·0735	182·6
	6	6718	34·77	47·97	13·20	·0717	183·6
	7	7016	34·85	45·93	11·08	·0602	184·1
	8	7044	34·88	45:75	10·87	·0592	183·6
	9	7921	35·11	40·68	5·57	·0301	185·2
	10	7910	35·10	40·74	5·64	·0301	187·4

represent A, the resistance, which in series with the condenser, would be equivalent to the electric absorption; and the abscissæ represent the period of the current in seconds. The curve proves to be a straight line, or A/T is a constant within the limits of error of the experiment. On account of this very simple relation connecting A and T, this condenser was exceedingly convenient for a test of the method.

The first test applied was to change the relations of the resistances in the different arms of the bridge. Table III

TABLE III.

Date, etc. 3–16–99	r=6536 R_2	R_3	R_4	R_1	R_1' Calculated.	A $(R_1'-R_1)$	T	$\frac{A}{T}$
1	509·2	5561	507·2	34·61	46·57	11·96	·0640	186·7
29								
2	509·2	5581	507·2	34·66	46·40	11·74	·0628	187·0
3	2071·	4598	99·56	34·65	44·97	10·32	·0558	184·9
4	2071·	4622	99·56	34·65	44·74	10·09	·0541	186·5
5	1009·5	6750	302·9	34·71	45·42	10·71	·0572	187·2
6	1009·5	6785	302·9	34·68	45·19	10·51	·0563	186·7
7	302·1	6732	1009·2	34·83	45·41	10·58	·0563	187·5
8	302·1	6728	1009·2	34·84	45·38	10·54	·0563	186·8
9	99·46	4511	2044·5	35·00	45·19	10·19	·0542	188·0
10	99·46	4511	2044·5	35·04	45·19	10·16	·0536	189·7

gives the results for R_2R_4 nearly constant and R_2/R_4 varied. The variation in R_2/R_4 was about 200 per cent and A/T is practically constant. The slight increase of A/T in the last two measurements is due to the larger current in arm 1 and a consequent heating of the condenser and also to the fact that after the coil of the electro-dynamometer had been heated slightly, it would be cooled a small amount before its resistance could be measured. Table IV shows the results when R_4

TABLE IV.

$R_4 = 1505{\cdot}8$ $r = 4810$

Date, etc.	R_2	R_3	R_1	Calculated. R'_1	T	$\frac{A}{(R'_1-R_1)}$	$\frac{A}{T}$	Mean.
4-19 1	2070·	76,600	34·68	40·70	·0312	6·02	192·9	194·8
118 5	2070·	74,200	34·80	42·02	·0367	7·22	196·7	
2	1009·	36,120	34·76	42·07	·0375	7·31	194·9	196·0
4	1009·	35,970	34·80	42·25	·0378	7·45	197·1	
3	99·48	3,542	34·75	42·30	·0386	7·55	195·6	195·6

is kept constant and R_2 and R_3 are varied. These also show A/T constant. It appears then from the above facts that A is a quantity independent of the relative values of the resistances in the different branches of the bridge.

In the next test the period was kept constant and the electromotive force acting on the condenser was varied about 300 per cent. The results of this test are given in Table V. The values for the higher electromotive forces are slightly greater, owing to the two heating effects mentioned above. Aside from

TABLE V.

$R_2 = 1008{\cdot}9$ $R_4 = 303{\cdot}8$

Date, etc.	R_3	r	R_1	Calculated. R'_1	$\frac{A}{R'_1-R_1}$	T	$\frac{A}{T}$	Volts e.m.f. acting on condenser $=V$
3-10-99								
1	6649	24,410	35·45	46·14	10·69	·0523	204·3	240·
27								
2	6593	24,410	35·34	46·53	11·19	·0562	199·3	240·
3	6797	12,490	35·13	45·17	10·04	·0508	197·6	152·
4	6777	12,490	35·15	45.31	10·16	·0511	198·9	152·
5	6606	6,348	35·03	46·56	11·53	·0584	197·3	77·
6	6473	6,348	34·96	47·57	12·55	·06418	195·5	77·
3-14								
6	6591	4,807	34·73	46·60	11·87	·0590	201·2	76·
28								
7	6803	6,371	34·79	45·14	10·35	·0515	201·1	142·
8	6732	6,371	34·78	45·61	10·83	·0540	200·6	142·
9	6555	18,830	35·01	46·74	11·73	·0567	203·5	243·

this, A/T is constant, i. e., A is independent of the current flowing through the condenser.

The variation in A/T due to changes of temperature was obtained as follows: in an opening made in the side of the box containing the condenser, a mercury thermometer was placed. The temperature indicated by the thermometer was of course not that of the inside of the condenser but that of the outer edge. The condenser, however, was kept within a degree or two at least of the desired temperature for some six or more hours before being used.

This method gave sufficiently accurate results, as there was no occasion for an accurate determination of the temperature.

TABLE VI.

Date, etc.	Temp. cent. t	$r=4810$ R_2	R_3	R_4	R_1	Calculated. R'_1	R'_1-R_1 A	T	$\frac{A}{T}$
11-16-99									
	19·3	709·0	2557	203·62	35·73	56·48	20·75	·0920	226·0
102									
1	22·0	707·8	2195	202·6	34·90	65·35	30·45	·1167	258·3
11-2-99									
7	22·2	707·8	2614	202·6	34·97	54·88	19·91	·0816	242·7
1	16·5	709·9	3271	203·0	34·40	44·08	9·68	·0543	178·6
12-8									
2	16·7	709·6	2862	203·0	34·44	50·04	15·60	·0816	191·3
106									
	20·2	2985·	2985	203·3	34·93	48·27	13·34	·0569	234·5
1	4·5	302·4	2696	407·3	34·55	45·87	11·32	·0752	150·9

Table VI gives the results of this investigation, and in fig. 4 they are plotted with temperatures as abscissas and A/T as

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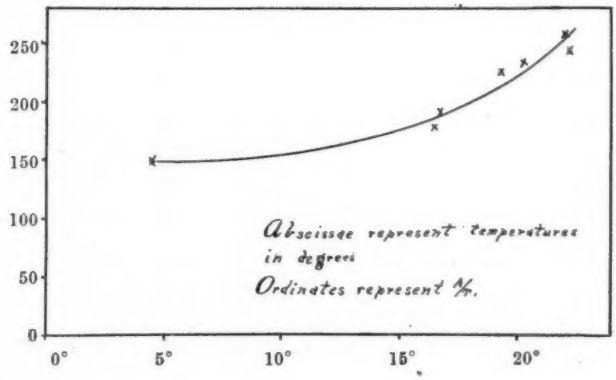

ordinates. It appears that at ordinary laboratory temperatures a variation of ·1° C. will cause a change of about 1 per cent in the value of A/T and consequently in A for a given T.* From this it appears that the slight variation noted above in the constancy of A/T would be easily accounted for by the changes of temperature due to the current or the gradual changes due to changes in the temperature of the room, since a series of observations usually occupied three hours or longer.

Table VII gives the results for the two $\frac{1}{8}$ microfarad condensers described above connected in parallel; and in fig. 5 the results are plotted as before.

TABLE VII.

$R_4 = 303{\cdot}3$ $\quad r = 4811$

Date, etc.		R_2	R_3	R_1	Calculated. R'_1	A $(R'_1 - R_1)$	T
11–29–99	1	409·7	2984·	34·07	41·66	7·59	·0271
105	2	409·7	2723·	34·07	45·59	11·52	·0345
	3	409·7	1807·	34·07	68·79	34·72	·0752
	4	409·7	1604·	34·07	77·49	43·42	·0893
	5	409·7	2454·	34·07	50·66	16·59	·0428
	6	409·7	3010·	34·07	41·30	7·23	·0239
	7	410·6	3157·	34·04	39·38	5·34	·0187

It was necessary to use the two in parallel in order to get sufficient current through the fixed coils of the electro-dynamometer. This was especially true for long periods, as then the impedance of the condenser increased and at the same time the available electromotive force from the dynamo decreased.

Capacity of a Condenser which shows Electric Absorption.

From the theory of electric absorption as based on the heterogeneous nature of the dielectric it appears that there should be a variable value of the capacity of such a condenser depend-

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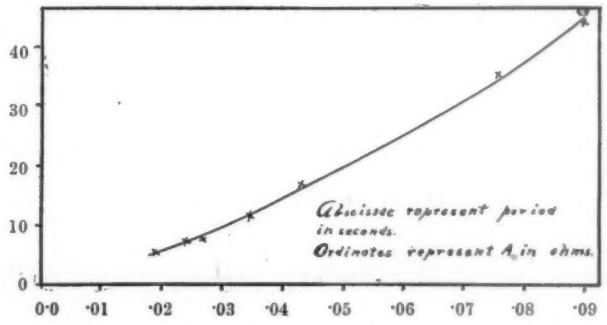
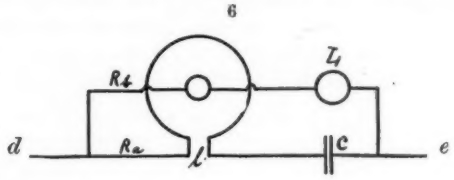


ing upon the period of the current flowing through the condenser. The method chosen for the measurement of capacity was one described in this Journal, December, 1897.

Method.—This consisted in the use of a divided circuit. One branch, a, contained a resistance R_a, either the fixed or hanging coils of the electro-dynamometer, and a condenser whose capacity c was to be studied. The other arm, b, contained a resistance R_b, a coil with which the capacity c is com-



pared, and either the hanging or fixed coils of the electro-dynamometer. Let L be the coefficient of self-induction of the coil plus that of the coils of the electro-dynamometer in that arm, and let l be the self-induction of the coils of the electro-dynamometer in the arm b. Let an electromotive force

$$E = E_o e^{(ibt)}$$

be applied to the terminals de. Now representing the maximum values of the current by C_a and C_b and the phases by ϕ_a and ϕ_b we have for the branch a

$$C_a e^{i(bt+\phi_b)} = E_o\left(R_a + ibl - \frac{i}{bc}\right)$$

and for branch b

$$C_b e^{i(bt+\phi b)} = E_o(R_b + ibL)$$

If we adjust the resistances until there is no deflection of the electro-dynamometer, we shall have the difference of phase $(\phi_b - \phi_a) = 90°$ or $\cos(\phi_b - \phi_a) = 0$. Further,

$$\frac{C_b}{C_a} e^{i(\phi_b - \phi_a)} = \frac{R_b + ibL}{R_a + ibl - \frac{i}{bc}} \qquad (12)$$

Hence since $\cos(\phi_b - \phi_a) = 0$ we must have the real part of this equal to zero, or

$$(1 - b^2cl)(b^2cL) = b^2c^2R_aR_b$$

or

$$\frac{L}{c} = R_aR_b\left(\frac{1}{1 - b^2cl}\right) \qquad (13)$$

As in the case considered above, a coil does not act as a self-induction alone but as a self-induction in *parallel* with a capacity due to the electrostatic action of the turns of the coil on one another. For this reason the above formula is not exact for any actual case; but there must be substituted above in place of R_b+ibL

$$R'_b + \frac{\frac{R''_b+ibL}{ibc'}}{R''_b+ibL-\frac{i}{bc'}} \qquad (14)$$

Substituting this in (12) we have

$$\frac{C_b}{C_a}\, e^{i(\phi_b-\phi_a)} = \frac{R'_b+\frac{R''_b+ibL}{ibc'R''_b+1-b^2c'L}}{R_a+ibl-\frac{i}{bc}}$$

$$= \frac{R'_b(1-b^2c'L)bc+R''_bbc+i[(b^2cc'R'_bR''_b+b^2cL)]}{R_a(1-b^2c'L)bc+(1-b^2cl)bc'R''_b-i[(1-b^2c'L)(1-b^2cl)-b^2cc'[R''_bR_a}$$

As before, the condition for no deflection is that the real part of this equals zero. Hence

$$b^2c[R'_b(1-b^2c'L)+R''_b][R_a(1-b^2c'L)c+R''_b(1-b^2cl)c'] = b^2c[R'_bR''_bc'+L][(1-b^2c'L)(1-b^2cl)-b^2cc'.R''_b.R_a]$$

Expanding,

$$R'_bR_a(1-b^2c'L)^2c+R''_b(1-b^2cl)(1-b^2c'L)R'_bc' + R''_bR_a(1-b^2c'L)c+R''_b{}^2(1-b^2cl)c' = R'_bR''_bc'(1-b^2c'L)(1-b^2cl)+L(1-b^2c'L)(1-b^2cl) - b^2cc'R''_bR_a(L+R'_bR''_bc')$$

Since c' is small, we can drop the term in c'^2. We have, on dividing by $(1-b^2c'L)(1-b^2cl)c$ and rearranging terms,

$$\frac{L}{C} = \frac{R'_bR_a(1-b^2c'L)}{1-b^2cl}+\frac{R''_bR_a}{(1-b^2cl)}+R''_b{}^2\frac{c'}{c}\frac{1}{(b^2-b^2c'L)} + \frac{b^2c'R''_bR_aL}{(1-b^2cl)(1-b^2c'L)}$$

or

$$\frac{L}{C} = \frac{(R'_b+R''_b)R_a}{(1-b^2cl)}+R''_b{}^2\frac{c'}{c}\frac{1}{(1-b^2c'L)} - \frac{b^2c'LR_aR'_b}{(1-b^2cl)}+\frac{b^2c'LR_aR''_b}{(1-b^2cl)(1-b^2c'L)}$$

Now, since in any case the last three terms are small, and $(1-b^2cl)$ and $(1-b^2c'L)$ are nearly one, they may be dropped from the last terms and we have

$$\frac{L}{C}=\frac{(R'_b+R''_b)R_a}{(1-b^2cl)}+\frac{c'}{c}R''_b{}^2+(R''_b-R'_b)b^2c'L \qquad (15)$$

Investigation—The arrangement is the same as in fig. 2. In position *a* and with a resistance in arm 4, electric absorption can be found. In position *b* and with a coil L in arm 4 in place of the resistance, the capacity of the condenser can be compared with the standard coil L. In formula (13) R_a includes not only the ohmic resistance of branch *a*, but also the added resistance due to electric absorption.

A preliminary investigation was carried out to find whether the correction due to the capacity of the coil C′ were appreciable and, if so, to ascertain its amount.

The method chosen was as follows: An arrangement was made as in fig. 2, except that in place of the condenser C the coil L with which the capacity of the condenser is to be compared is placed in arm 1 of the bridge. The arrangement was first balanced with a direct current; and the value of R_1 as measured and as calculated from R_2, R_3, R_4 were the same. In Table VIII are given the results for R'_1 as calculated for three

TABLE VIII.

$R_2=1010$ $R_4=912{\cdot}5$ $r=4810$ Coil A=5·3 henry

Date		R_3	R_1	R'_1	T	$D=R'_1-R_1$	
				By formula 13			
4·20	1	4080	224·6	225·8	·0188	1·0	
	2	4092	224·8	225·2	·0488	·4	
	3	4074	225·0	226·2	·0182	1·2	
	4	4034	225·0	228·4	·0182	3·4	with ·01 microfarad in parallel with coil.

If formula (15) is used in calculating R'_1 it is 226·2. Hence D=1·2 as without condenser.

periods of the current. In all three cases R'_1 is greater than R_1 by an amount D. A third observation was made with a condenser of ·01 microfarad capacity shunted across the terminals of the coil. The corrected formula (7) was tested in this way. The result gives the same value of D, with or without the condenser, thus verifying the formula. By assuming the quantity D as entirely due to the electrostatic action of the coil, which if not absolutely true, the formula will at least give a value of c' the equivalent capacity of the coil, which may be used as the limiting value. The value of c' is ·006 microfarad. In formula (15) the last term will be very small as

compared to the first for any values of b used in this work. The second term will in the most unfavorable circumstances amount to only 1 part in 10,000, so that the corrections due to the electrostatic action of the coil may be entirely neglected.

The next point investigated was the correction due to the electric absorption. In these observations the absorption was determined, the capacity then measured, and the electric absorption again determined. In Table IX are given the

TABLE IX.

r=4811 R_2=707·8 R_4=202·6 L=5·302 in 2 and 5·318 in rest.

Date, etc.		R_3	R_1	Calculated. R'_1	$\frac{A}{(R'_1-R_1)}$	T	$\frac{A}{T}$	Mean. $\frac{A}{T}$
	1	2195·	34·90	65·35	30·45	·117	261·	
N-16								253·
	7	2614·	34·97	54·88	19·91	·0816	244·	

	R_a	R_b	T	A	Corrected for electric absorption. R_a	R_b	$10^6 \times \frac{L}{R_a R_b} = C$
2	238·2	2604	·121	30·6	268·8	2604	7·574 M.F.
3	228·8	3053	·103	26·1	——	3079·	7·549
4	328·2	2119	·103	26·1	——	2145·	7·554
5	431·5	1602	·102	25·8	——	1628·	7·569
6	531·5	1302	·0908	23·0	——	1325·	7·552

results with the condenser in one arm and then changing to the other, and also changing the resistance in series with the condenser. The results are corrected for electric absorption and the change in L due to the change of c and the coil from one arm to the other, caused by the coils of the electro-dynamometer having different coefficients of induction. The greatest difference between two determinations under these different conditions is 3 parts in 1,000.

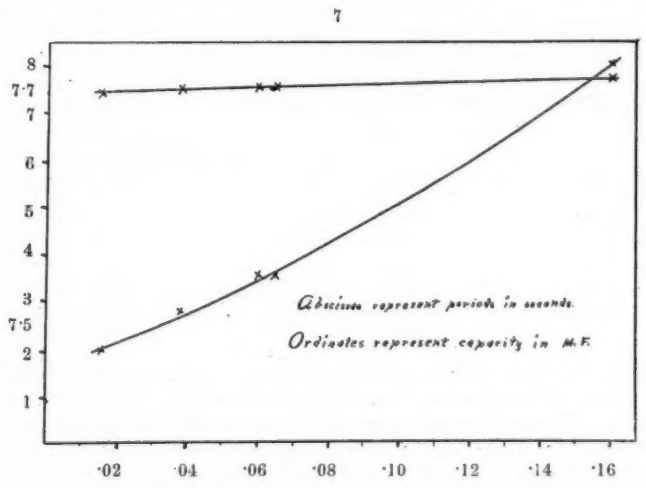
The change of capacity with the period of the current was now tried. Table X shows the results of the investigation. The error of each observation has a limit of about 1 part in 1,000, if the observations are compared among themselves, while the actual error, as compared with the true ratio $\frac{L}{C}$ may be in error two or three times this; but we are not particularly concerned here with the actual value, but merely the change with change of period. In fig. 7 the results are plotted on two scales. The results for the capacity seem to agree very well

TABLE X.

L=5·318

Date, etc.	R_2	R_3	R_4	R_1	r	R'_1	A	T	$\frac{A}{T}$
	709·0	2556·8	203·62	35·73	4811	56·46	20·73	·0919	225·8

				Corrected for electric absorption.			
R_a	R_b	T	A	R_a	R_b	$10^6 \times \frac{L}{R_a R_b} = C_1$	$C = \frac{c_1}{1 - b^2 c l}$
429·2	1589·1	·160	36·2	429·2	1605·3	7·719	7·719
429·3	1628·1	·0654	14·8	429·3	1642·9	7·540	7·540
429·3	1640·0	·0389	8·8	429·3	1648·8	7·513	7·512
429·4	1651·0	·0151	3·4	429·4	1654·4	7·487	7·480
429·4	1628·0	·0601	13·8	429·4	1641·8	7·543	7·543



with the theory. The condenser has a capacity which shows a slight variation with the period of the current. The capacity increases with increase in the period of the current, as shown by the theory; and in amount it is somewhat less than as the square of the period.

II. Detection of Short Circuits.

A very useful application of the Wheatstone bridge is its use for the detection of short circuits in coils of wire. If a mass of metal or a closed coil of wire is held near a coil of wire carrying an alternating current, there will be induced in it certain currents. Hence there must be more energy supplied to the primary circuit to keep up the current. This extra

consumption of energy will manifest itself by an apparent increase in the resistance and consequently a greater i^2R loss. This fact is made use of in the following method for the detection of short circuits in coils and was suggested by Professor Rowland.*

The method is as follows: the connections are as in fig. 2, with the exception that a coil of wire is introduced in arm 1 in place of the condenser. If the resistances are now balanced until there is no deflection of the electro-dynamometer, and a mass of metal approaches the coil, there will be a deflection of the electro-dynamometer; owing to the increase in the effective resistance of the arm 1. If a coil of wire whose ends are not connected be laid on top of the coil in arm 4 there will be no deflection, while if the ends are connected or if there is a short circuit in the coil there will be a deflection.

TABLE XI.

	$R_2=1010$	$R_4=1507$	$R_1=225{\cdot}7$	$T=\cdot015$	
No. of turns.	Dia. of wire.		Uncorrected. R'_1	D	R_c
0	—	6711	226·8	0	
2· 14	1·59	5882	258·8	9·15 cm.	32·0
3· 22	·62	6497	234·3	2·21	7·5
5· 25	·44	6520	233·4	1·90	6·6

Table XI shows the sensitiveness of the method. The coil A of 5·3 henrys was used. The bridge was balanced and then small coils of wire the same size as the inner diameter of the coil were placed on the coil and the deflection noted; and the apparent increase of resistance was determined in the same manner as the electric absorption in the case when the coil L was replaced by a condenser. Column D gives the deflection after the coils were placed on the large coil in arm 1 and R_c is the apparent increase in resistance of arm 1. It appears from this table that with a coil of the size used, a short circuit in another coil of same size could be detected, even though the coil were of quite fine wire and only one turn was crossed. Other conditions being the same, the sensitiveness varies directly as the cross section of the wire in the coil to be tested, if the resistance of the contact between the two ends of wire is neglected. In cases where small coils are to be tested, the sensitiveness may be increased by filling the center of the coil with iron. And of course as short a period of current as available should be used.

* This Journal, December, 1897.

III. Hysteresis.

The arrangement used for the determination of losses of energy due to hysteresis and Foucault currents is the same as for the determination of electric absorption, with several additional elements.

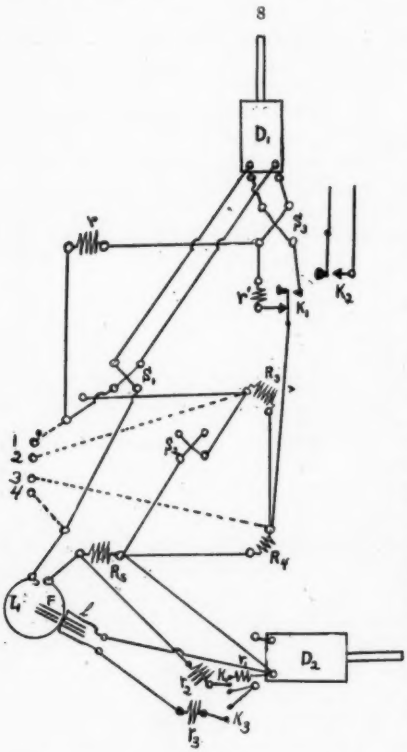


Fig. 8 shows the arrangement used. All the arms are the same as in fig. 2 except arm 1. Arm 1 contains a coil L. In this coil is placed the iron to be tested, F. l is a small coil of wire surrounding the iron, and used to determine the induction through the iron. The two coils of the electro-dynamometer D_2 are connected in series. The key K_3 serves to put the coil l, the resistance r_3 and the coils of the electro-dynamometer in series. By noting the deflection produced by the current induced in l, the induction may be calculated, the electro-dynamometer having been previously calibrated.

R_5 is a small resistance in arm 1. A small current is shunted off from the terminals of R_5 and can be sent through the resistance r_2 and the electro-dynamometer by the key K_4; and thus the total current in arm 1 may be determined.

Measurement of the current.—The calibration of the electro-dynamometer showed the current to be quite accurately proportional to the square root of the deflection ($\sqrt{D}$). A deflection of 1 cm. corresponds to a current of ·00213 ampere. We shall then have the total current in arm 1

$$C_1 = \cdot 00213 \sqrt{D} \frac{r_2 + R_5}{R_5}$$

In place of measuring the current by an electro-dynamometer, in some cases a small ammeter might be used, but as the current enters as a square in the energy loss, it must be accurately determined.

Determination of the induction: For the determination of the induction several different forms of the secondary coil were tried. Coils of the same size as the internal diameter of the coils A and C were first used. These were found unsuitable, however, as a considerable current was induced in them, even when they contained no iron, and their coefficient of self-induction was not negligible. The best form was found to be a coil of fifty turns, just large enough to contain the iron used. No measurable current was induced in this, when it contained no iron, and its self-induction was negligible. The e.m.f. around the circuit when K_1 is closed will be E_1 where

$$E_1 = \sqrt{D} \times \cdot 00213 \times R \text{ volts}$$

Now let N be the number of turns in the coil l and S the average cross section of the iron surrounding the coil L and we have the induction per sq. cm. B

$$B = \frac{\sqrt{D} \times \cdot 00213 \times R}{N \times 4 \cdot 44 \times r} \times 10^8 \text{ c. g. s. units}$$

where N is the number of complete periods of the current.

Energy loss.—The energy loss due to hysteresis is ordinarily expressed as a certain loss per c.c. of iron per cycle. Energy loss $= i^2 R t$.

If C_1 is the current in arm 1, H the total added resistance due to the hysteresis and Foucault currents, v the volume of the iron used, we have the energy loss per cycle,

$$C_1^2 \frac{H}{V} T$$

since t will equal T, the period of the current.

Experiment.—The iron used was ordinary transformer iron. The plates were L-shape, and could be fitted about the coil C very nicely. In the first place the uniformity of B was tested for different quantities of iron. A slot was cut in the center of one side of an L plate, thus dividing the side into two parts which were made as nearly equal as possible. A coil of wire of one hundred turns was wound on each of these parts of the iron. By noting the deflection produced by the two coils in succession when the iron was placed in coil A, the relative value of B close to the coil A and farther away could be tested. By placing in the coil different numbers of the plates and

placing the test plate at different points, the uniformity of B was tested.

Table XII shows the results of this test. It appears from this table that with either 8 or 10 pieces of iron B is practically uniform. With fewer pieces the induction was greatest next the coil, and when more were used the magnetism was not as great in the central pieces.

TABLE XII.

No. of pieces of iron.	Test plate on outside of bundle. Lower coil.	Upper coil.	Per cent var. B.	Test plate next to outside plate. Lower coil.	Upper coil.		Two plates outside of test plate. Lower coil.	Upper coil.	
2	6·51	6·03	3·	—	—	—	—	—	—
4	4·14	3·82	3·	—	—	—	—	—	—
6	3·60	3·48	1·9	3·60	3·62	·7	—	—	—
8	2·65	2·55	2·	2·71	2·71	0·	—	—	—
10	—	—	—	—	—	—	2·75	2·85	2·

Table XIII shows the results of a series of measurements, and in fig. 9 a curve is plotted showing the relation between B and the energy loss per cycle.

TABLE XIII.

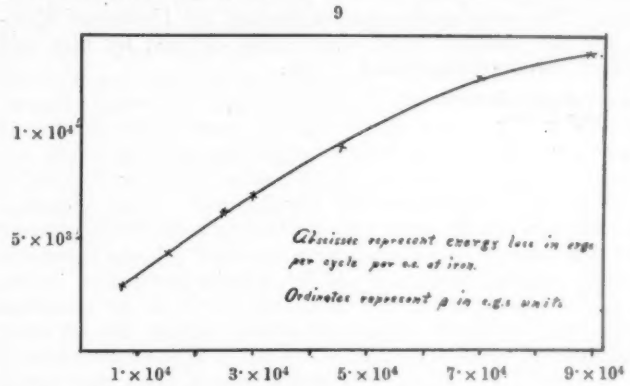
Weight of iron=340 g. Volume=43·3 cc. Area section=·981 sq. cm. D_1=deflection dynamometer by current C. D_2=same for secondary current.

3-21-00 -115-	R_2	R_3	R_4	R_1	R'_1	H	T	D_1	D_2	r_1	r_2
1	913·2	2945·	1011·	148·3	313·5	165·2	·0277	3·62	3·18	166·7	59·72
2	505·9	2140·	1508·	148·3	356·5	207·8	·0280	5·85	7·40	166·7	59·72
3	208·6	1106·	2016·	148·3	380·2	231·9	·0275	8·78	14·70	166·7	59·72
5	1769·	2408·	507·5	148·3	372·8	224·5	·0276	9·00	3·00	166·7	129·72
6	1563·	2100·	507·5	148·3	377·7	229·4	·0273	10·61	3·86	166·7	129·72
8	1060·	1431·	507·5	153·0	375·9	222·9	·0267	4·00	6·95	377·0	129·72
9	503·1	1671·	1010·5	153·0	304·2	151·2	·0254	9·60	14·10	377·0	129·72
11	206·9	1639·	2014·	153·1	254·1	101·1	·0255	18·10	14·36	377·0	149·8

	B	C_1	H per c.c.	C_1^2HT
1	$2·88 \times 10^3$	·0262	3·815	$7·10 \times 10^3$
2	$4·32 \times 10^3$	·0337	4·799	$1·524 \times 10^4$
3	$6·17 \times 10^3$	·0412	5·356	$2·51 \times 10^4$
5	$6·07 \times 10^3$	·0418	5·185	$2·50 \times 10^4$
6	$6·86 \times 10^3$	·0454	5·298	$2·98 \times 10^4$
8	$8·92 \times 10^3$	·0576	5·148	$4·56 \times 10^4$
9	$1·207 \times 10^4$	·0891	3·482	$7·00 \times 10^4$
11	$1·318 \times 10^4$	·1226	2·335	$8·93 \times 10^4$

SUMMARY.

From the above it appears that the method described is a perfectly good method for the measurement of electric absorption. In all cases tried the electric absorption has acted as a resistance in series with a capacity. This resistance is independent of the current. The temperature has a decided effect. The value of this absorption increases very rapidly with rising temperature. The theory as given above appears to be verified



by the results in as far as a condenser possessing electric absorption may be considered as a capacity in series with a resistance, both of which depend upon the period of the current. While the variation is in the proper direction in each case, its rate of change with the period does not agree with the theoretical formula, especially in the case of the wax and paper condenser.

It also appears that the method given is a good one for the determination of the capacity of a condenser, which shows electric absorption. If electric absorption is corrected for, the capacity of such a condenser is a quantity which can readily be determined, and may be compared with a self-induction standard to 1 part in 1,000. It also appears that no correction is necessary for the electrostatic action of the turns of the standard coil on one another, at least if the relative size of coil and condenser is properly chosen, and if the resistance of the coil is not too large as compared with the total resistance in the branches of the circuit.

The method given for the detection of short circuits in coils proves to be an exceedingly sensitive one.

The method described for the measurement of losses due to hysteresis and Foucault currents gives very good results. Its

chief advantage lies in the fact that a very small quantity of the material is necessary. In the experiment only 360 grams were used. Much less than this amount could be used, with nearly as great accuracy as in the case given. For the value of the resistance H could be increased by decreasing the period of the current used.

In conclusion I wish to express my sincere appreciation of much assistance received from Professors Rowland and Ames during three years spent in study at the Johns Hopkins University. The investigation was suggested by Professor Rowland, and the methods used were those devised by him and described in the articles noted above.

Johns Hopkins University,
May 1, 1900.

ART. XIII.—*Some New Jurassic Vertebrates;* by WILBUR C. KNIGHT. Paper No. III.

FOR several years the Geological Department of the University of Wyoming has been directing its entire energy and what little money it could procure toward building up a collection of Jurassic vertebrates. On account of splendid success in the field the collection has already assumed considerable proportions and from time to time new animals are being discovered. The bulk of the material at the present time is Dinosaurus, but the marine beds of the Rocky mountain Jurassic have not been neglected and a few marine reptiles have been discovered. Among these are two new species of the order of Sauropterygia, which belong to two genera, neither of which have been reported from the Rocky mountain Jurassic; one of them being a Plesiosaur and the other a Cimoliosaur. With this addition to the fauna of the Eastern Rocky mountain region, there are now known two species of Ichthyosaurs* and three species of the Plesiosaur† type. The two skeletons which form the basis for this paper are not as complete as one would like to have them for generic and specific determinations, but there are sufficient remains in each case to give a very good idea of the species.

Plesiosaurus shirleyensis sp. nov.

The remains of this species consists of vertebra from all parts of the column; there being many from the cervical region; numerous teeth and fragments of teeth; a distorted portion of the lower jaw and many phalanges. Teeth large and numerous, incurved, elliptical in cross-section, interior surface of the teeth covered with numerous very fine angular striæ, exterior surface nearly smooth and showing faint marks of striæ. The greater portion of one side of the lower jaw measures ·280^{m} in length and has a depth of ·035^{m}. The vertebra are slightly biconcave, and all wider than long; but in the dorsals and posterior cervicals the length and breadth are nearly equal. The neural spines were found attached to the centra of the cervical vertebra, but the suture was obliterated. On the anterior caudles the neural spines are of considerable height.

Nothing of importance is known of the dorsal vertebræ, excepting that they are slightly biconcave and circular in

* Baptanodon discus Marsh; Baptanodon nateus Marsh.
† Megalneusaurus rex Knight. See this Journal, vol. v, p. 378.

transverse sections. Anterior caudles are flattened beneath and have two large circular facets for the articulation of the chevrons; neural arches firmly attached to centra. The basal phalanges have compressed, angular shafts, their shape depending largely upon their position in the paddle. Those in the central region approach a quadrangular section; while those on the exterior are V-shaped in cross-section with the opening of the V to the interior of the paddle. Terminations of phalanges rugose and strongly biconvex.

Measurements.

	M.	
Length of fragment of lower jaw	·280	
Depth of fragment of lower jaw	·035	
Length of teeth about	·049	
Transverse diameter of teeth at base of striations	·006	
Length of striated portion	·014	
Dorsal vertebra.		
Length	·048	
Width	·055	
Height to neural platform	·045	
Posterior cervical vertebra.		
Length	·050	
Width	·055	
Height to neural platform	·045	
Height of process from neural platform	·090	
Caudle vertebra (anterior).		
Length	·029	
Width	·046	
Height of neural platform	·034	
Phalanges.	M.	
Basal.	large.	medium.
Length	·049	·045
Width, distal end	·022	·020
Width, proximal end	·023	·020
Width of shaft	·015	·012
Intermediate.		
Length	·035	·030
Width, distal end	·020	·018
Width, proximal end	·022	·019
Width of shaft	·013	·013
Terminal (nearly).		
Length	·025	·021
Width, distal end	·012	·012
Width, proximal end	·013	·013
Width of shaft	·008	·007

This animal had a long neck and large paddles; but did not attain a length of over fourteen to sixteen feet. It was dis-

covered in the Shirley* stage of the Jurassic rocks of Albany County, Wyoming, and was associated with *Baptanodon discus*, *Ostrea strigilecula*, *Camptonectes bellistriatus* and *Astarta Packardi*. Type specimen marked letter H in the collection of the University of Wyoming.

Cimoliosaurus laramiensis sp. nov.

This specimen consists of numerous vertebra and nearly a complete front limb. The humerus conforms to the general shape of Cimoliosaurs, but whether it belongs to the division where ulna and radius articulate with the humerus or to the other group where the pisiform is present, cannot be satisfactorily determined. There are two very distinct facets at the distal end of the humerus; the remainder of the margin is rounded and shows no sign of a pisiform. The facet for the radius occupies over one-half of the width of the expanded end, and is nearly flat. The humerus is a short, heavy bone, broadly expanded distally, and the post-axial border slightly recurved. Trochanteric ridge very prominent; shaft transversely elliptical with a rugose prominence on the anterior border, ·120^{m} below the head; apparently for the attachment of a large muscle; head spherical. Radius V-shape with the angle truncated and toward the ulna. The articulations of the ulna slightly convex; the proximal end very wide, distal narrow, and the ulna and radius evidently uniting without a central opening; exterior margin curved and very thin. Ulna not known. There are six carpal bones, all angular, but their relative position has not been determined.

Metacarpals and basal phalanges only slightly compressed and with flattened shafts, the upper surface slightly rounded, with a depression on either side, making a transverse section as figure in plate B, No. 1; they are also biconvex with pitted terminations. The terminal phalanges are much more compressed and without the depressions on the surface. All the vertebra wider than long and moderately biconcave, with neural arches firmly attached. Dorsal vertebra with a forward overhanging of the centra as is usually found in Cimoliosaurs, and circular in transverse section. Cervical vertebra numerous and anterior ones very small.

Caudle vertebra large, elliptical in transverse section. Anterior ones with large transverse processes, and large angular chevron facets.

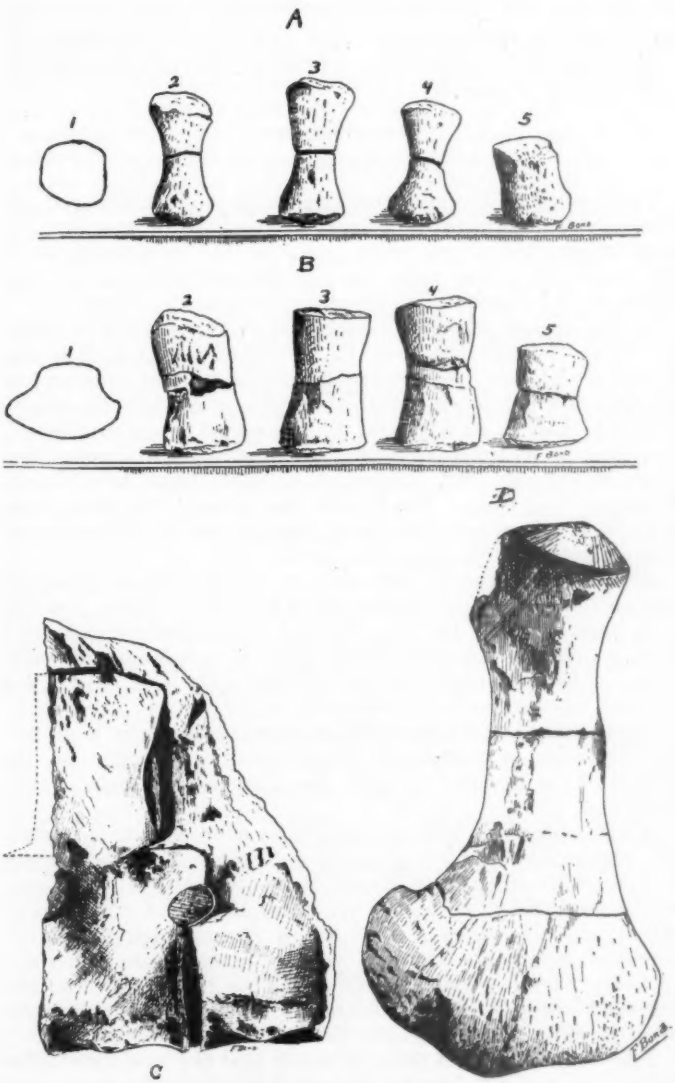
*This is a new name applied to the Rocky Mountain marine Jurassic. See paper presented by me to the Geological Society of America, December 30, 1899.

Measurements.

	M.
Length of humerus	·312
Width of humerus, distal end	·136
Thickness, maximum, of distal end	·041
Height of head	·100
Width of head	·068
Width of shaft humerus midway	·066
Thickness of shaft of humerus midway	·051
Radius.	
Length	·095
Width of proximal articulation	·085
Width of distal articulation	·064
Thickness on interior edge	·033
A. Phalanx.	
Basal.	
Length	·053
Width of base	·030
Width of shaft	·023
Width at distal end	·027
Vertebra.	
Dorsal.	
Length	·037
Width	·045
Height of centrum	·040
Concavity of ends of centrum	·006
Anterior caudle.	
Length	·032
Width	·050
Height of centrum	·035
Concavity of ends of centrum	·006
Cervicals.	
Anterior.	
Length	·022
Width	·030
Height	·032
Posterior.	
Length	·026
Width	·041
Height	·032

This was a small animal, probably not more than twelve feet in length. It was found associated with Baptanodon remains in Shirley stage of the Freezeout Hills, Carbon County, Wyoming. This specimen is marked letter T in the collection of the University of Wyoming.

Geological Department,
University of Wyoming, April 6, 1900.



EXPLANATION OF FIGURES.

A and C.—*Plesiosaurus shirleyensis.*
A, No. 1.—Transverse section of a basal phalanx. ($\times \frac{3}{5}$)
Nos. 2, 3, 4, 5, basal phalanges. ($\times \frac{7}{16}$)
C.—Side view of cervical vertebra. ($\times \frac{2}{5}$)
B and D.—*Cimoliosaurus laramiensis.*
B, No. 1, transverse section of a basal phalanx. ($\times \frac{3}{5}$)
Nos. 2, 3, 4, 5, basal phalanges. ($\times \frac{7}{16}$)
D.—Humerus. ($\times \frac{1}{4}$)

ART. XIV. — *On Carnotite and Associated Vanadiferous Minerals in Western Colorado;* by W. F. HILLEBRAND and F. LESLIE RANSOME.

INTRODUCTION.

W. F. HILLEBRAND.

THE rather wide-spread occurrence in western Colorado of considerable quantities of a canary-yellow ore of uranium has been known for a few years past. It has been marketed to the extent of a few tons, but its mineralogical nature was unknown or incorrectly surmised until about a year ago.

In the spring of 1899 a specimen of this ore first reached my hands through Dr. Geo. P. Merrill of the U. S. National Museum, and was speedily recognized to contain a mineral or minerals new to science. Within a week appeared the announcement by MM. C. Friedel and E. Cumenge* of a new mineral, carnotite, a hydrous vanadate of uranium and potassium, obtained through Mr. Poulot of Denver, from Roc Creek, Montrose Co., Colo. Mr. Poulot had already identified vanadium in it. It was at once seen, despite certain differences in composition, that the two were identical.

According to the French authors the mineral is of simple composition, as above expressed, with only a little iron and mere traces of Al, Ba, Cu, Pb, and also according to M. and Mme. Curie, of the radio-active substances radium and polonium. The empirical formula $2U_2O_5$, V_2O_5, K_2O, $3H_2O$, was assigned to it, some doubt attaching to the water.

Since then I have been able to examine carnotite from several localities in western Colorado, finding in each case the same lack of agreement with the analyses of Friedel and Cumenge.

While engaged in this work there were brought to my attention certain more or less greenish sandstones from the vicinity of Placerville on the San Miguel River, San Miguel Co., Colo., which were said to be highly vanadiferous and of considerable extent, and in which a zone a few inches thick was rather strongly impregnated with a yellow mineral resembling and probably identical with carnotite. This latter appeared also scattered through the sandstone at other points in sporadic small patches, sometimes only visible by aid of a lens.

This occurrence led to the thought that the carnotite bodies farther west might also be associated with existing or depend-

* Bull. Soc. Chim. de Paris (3), xxi, 328, 1899; Bull. Soc. Franc. Min., xxii, 26, 1899; Comptes Rend., cxxviii, 532, 1899; Chemical News, lxxx, 16, 1899. The papers as published in French differ slightly.

ent on preëxistent vanadiferous sandstones. For the carnotite of Montrose and Mesa Counties, as mentioned by the French authors, occurs mixed in all proportions with quartz-sand grains, the remnants beyond doubt of former sandstone bodies, and it was soon recognized that in the carnotite bodies the vanadium existed in two conditions, the larger part by far as pentavalent vanadium in the easily soluble carnotite, and a smaller and sometimes hardly distinguishable portion as trivalent vanadium in a much less soluble silicate which was free from uranium.

It was hoped that by a field reconnaissance, observations bearing on these points would be obtained and material assembled which would on analysis help to solve the nature and explain the association of these two entirely different classes of mineral substances.

The field and microscopical observations of Messrs. Ransome and Spencer are embodied in the pages immediately following these introductory remarks. Unfortunately their collections, except from Placerville, came to hand so late that the chemical work on the more western occurrences has been confined to the carnotite bodies alone, of which material was already in my hands. Greenish sandstones have been observed by Messrs. Ransome and Spencer in those regions, but whether any of them are highly vanadiferous, or what their connection with the carnotite may be, remains yet unknown. The only two examined did not owe their color to vanadium. Meanwhile the chemical results thus far obtained, which it is advisable to put on record at once, will be found in the concluding section of this paper.

In this place it is my pleasure to record my appreciation of the readiness with which the following gentlemen have supplied me with material for study: Messrs. Poulot and Voillequé of Denver, Mr. A. B. Frenzel of Placerville, and Mr. J. R. Duling of Paradox. These gentlemen have, also, not hesitated to furnish me with all information at their disposal as to occurrence, etc., of these interesting ore bodies.

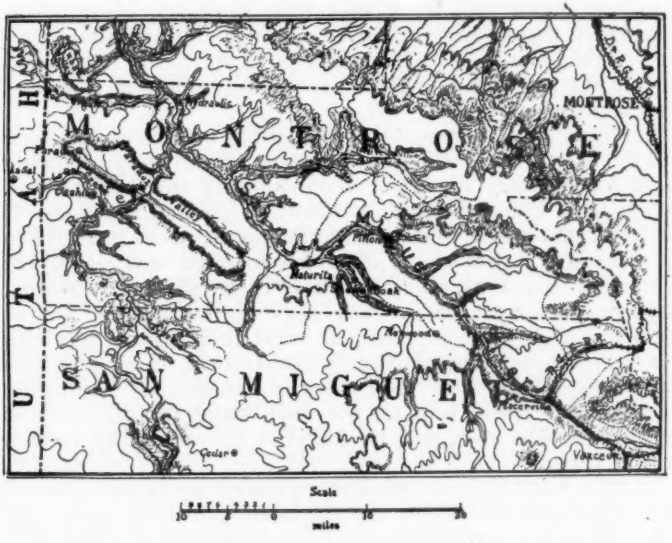
Occurrence of the Uranium and Vanadium Ores.

F. L. RANSOME.

General.—In the autumn of 1899, a brief reconnaissance trip was undertaken into the western portions of San Miguel, Montrose and Mesa Counties, near the Utah-Colorado line. I was accompanied by Dr. A. C. Spencer, whose knowledge of the stratigraphy of the region was of great assistance. The primary object of the expedition in accordance with a suggestion from Mr. S. F. Emmons, was to investigate the

copper deposits of La Sal Creek, Paradox and Sinbad Valleys, and the vicinity, which had been responsible for some mining excitement a few months previously. A memorandum from Dr. W. F. Hillebrand, received just before starting, indicated that it would be well also to examine certain prospects on which some preliminary work had been done, looking toward the extraction of ores of uranium and vanadium. It is to the latter that these present notes are confined.

1



The most convenient way of reaching Paradox Valley was found to be the stage road, which, starting from Placerville, a settlement and station on the Rio Grande Southern R.R., runs by way of Norwood, Shenandoah and Naturita to Paradox, a distance of 60 or 70 miles.

The region can also be reached from the west by way of Moab, in Utah. The Placerville route and the general geographical relations are roughly indicated in the accompanying sketch map, fig. 1.

The topography of the region west of Placerville is that characteristic of the "mesa country" of western Colorado and southeastern Utah. Broad stretches of plateau are intersected by steep-walled cañons and cliff-encircled valleys. The underlying rocks comprise the "red beds" of the Dolores forma-

tion* (Triassic), the La Plata formation (Jurassic), the McElmo formation (Jurassic), the Dakota sandstone (Cretaceous), and the Mancos shales (Cretaceous). Carboniferous rocks occur in Sinbad Valley, and a series of gypsum-bearing shales of unknown age in the bottoms of Sinbad and Paradox Valleys, but as the ore-deposits to be described all occur in the beds of the La Plata and McElmo formations, these older rocks need not be again referred to. The sediments making up these various formations lie usually nearly horizontal, but they are sometimes flexed and frequently faulted.

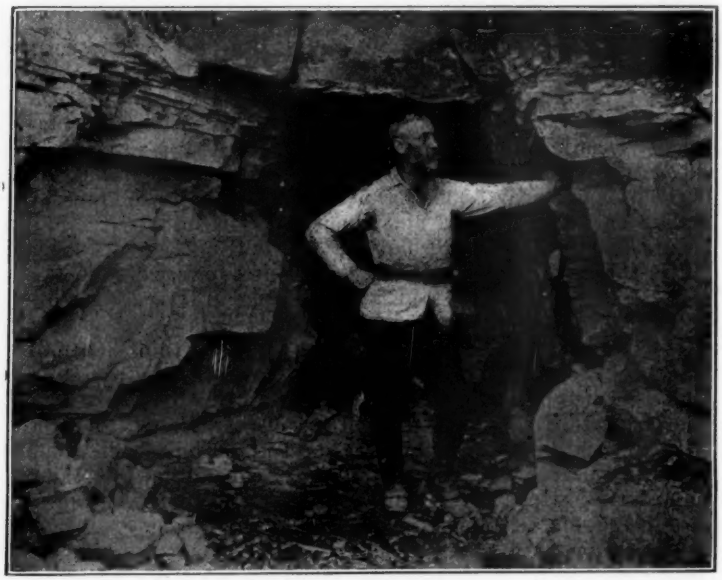
In all of the prospects examined, the ore of uranium occurs in the form of the recently described bright yellow carnotite. In one case this is intimately associated with a dull olive-green mineral which according to Dr. Hillebrand is either identical with, or very closely allied to, the vanadium-mica roscoelite. Deposits of one or both of these minerals occur widely scattered over San Miguel and Montrose Counties, Colorado, and in the Blue Mountain (Sierra Abajo) district of southeastern Utah; but a portion only of the known deposits were personally examined.

The Placerville Deposits.—These are essentially vanadium deposits, and occur 4500 feet nearly northeast of the railway station near Placerville, and about 1000 feet above the San Miguel River. The lower 900 feet of the San Miguel cañon is cut in the typical "red beds" of the Dolores formation. Above the Dolores comes the La Plata sandstone in typical development as described in the Telluride folios, viz., two heavy beds of light-colored sandstone, separated by a much thinner bed of dark limestone. The roscoelite occurs as an impregnation in the lower bed of the La Plata sandstone, about 100 feet above the base, and just beneath the bed of dark limestone. All the beds at this point are practically horizontal. The dark green vanadiferous sandstone occurs in a nearly continuous band, approximately parallel to the bedding planes, and varying in thickness from a few inches up to five or six feet. This band extends along the sandstone cliffs for an estimated distance of about 2000 feet. The roscoelite occurs more or less thoroughly impregnating portions of the fine-grained sandstone which constitutes the mass of the bed. It sometimes makes up more than 20 per cent of the vanadiferous facies. Normally the sandstone of this lower bed of the La Plata is light buff in color, with patches, mottlings, and stripes of pale pink, the latter color being apparently due to small amounts of ferric oxide. But when richly impregnated with roscoelite, this light-

* The formation names used in these notes are those adopted by Cross in the text of the Telluride Folio, of the U. S. Geol. Survey. The reader is referred to this folio for fuller descriptions.

colored sandstone becomes dark olive-green, the contrast being most marked when the cliffs are wet. Although fairly continuous for the distance stated, this zone of vanadiferous sandstone is by no means regular. It varies much in thickness, and in one place splits into two or more branches. At some points two or more distinct streaks of roscoelite-bearing sand were found at different horizons in the main sandstone bed. The carnotite is not nearly so abundant as the roscoelite at this locality. It occurs as minute yellow specks in the sandstone, and particularly as thin horizontal seams or streaks near the bottom of the vanadiferous zone.

2



The work thus far done on the several claims which have been located along these deposits is of the most superficial character. On the Canary claim a tunnel of about 18 feet has been run by Mr. A. B. Frenzel which exposes a typical section of the impregnated zone (fig. 2). The roof of the tunnel is formed by the underside of the bed of dark limestone previously referred to. This limestone is underlain by a few inches of sandy limestone which passes into the light-buff La Plata sandstone without break. The latter contains abundant calcite

as a cement or matrix for the sand grains. At a distance of a foot below the limestone, the sandstone shows, on close inspection, numerous specks of carnotite and gives a qualitative reaction for vanadium (Hillebrand). Examined in thin section under the microscope, this portion of the bed shows a fine-grained homogeneous sandstone, in which well rounded grains of quartz are held together by a rather abundant matrix of calcite. The latter is crystallized as a fine granular aggregate and includes small indeterminable particles of various kinds. Many of the quartz grains as seen in section are entirely surrounded by calcite, and so isolated from adjacent grains. A pale lemon-yellow substance occurs sporadically in the section as an interstitial material between the quartz grains. This is probably the carnotite which was seen as small yellow specks in the hand specimen. It is very minutely crystalline, recalling the habit of some obscure chloritic aggregates in decomposed igneous rocks, and is too indistinct for successful optical study. Small crystal grains of zircon are scattered through the sandstone, and are readily concentrated in the residue after treating with hydrofluoric acid.

In the next two feet below where it exhibits the foregoing facies, the sandstone becomes pinkish in color, due to the presence of ferric oxide, and the lens fails to reveal any roscoelite or carnotite. But just below the pink coloration, the sandstone begins to show yellow and green specks. The latter especially become more numerous and larger, until at from 3 to 4 feet below the limestone the sandstone has a decided green tint. This deepens, going downward, until near the floor of the tunnel the sandstone is a deep uniform olive-green, rich in roscoelite (over 20 per cent) and showing many small yellow specks of carnotite. This is regarded as the first-class ore, and the chief value of the deposit is supposed to be in its vanadium, the uranium being very subordinate. In this respect the Placerville deposit differs from those on La Sal and Roc Creeks, presently to be described, where the mineral sought for and occurring most abundantly is carnotite.

Thin sections of the green-spotted sandstone, when examined microscopically, resemble those of the light-buff sandstone just above it, as far as character of quartz grains and relative abundance of matrix are concerned. But the character of the matrix or cement is different. Calcite is much less abundant and its place is largely taken by roscoelite. This is grass-green in thin section, and might readily be mistaken for indistinct wisps and areas of chlorite. It sometimes forms a distinct envelope around the quartz grains, showing an indistinct foliated or fibrous structure normal to the surface of the latter.

The uniformly dark green sandstone richest in roscoelite does not effervesce with acids and shows no calcite cement in thin section. The usual quartz grains are held together by roscoelite. This is crystalline, but the highest available powers show only an indistinct and minute foliation, such as may be observed in some very finely crystallized chlorites.

Close to the floor of the tunnel is a fairly regular, nearly horizontal streak of carnotite, varying in width, but usually less than an inch, and showing noticeable diminution in thickness in the face of the tunnel. This small seam is not solid carnotite, but is merely a zone in the sandstone impregnated with the bright-yellow uranium mineral. It is not nearly so continuous as the main vanadiferous belt, and was seen only at three or four places along the 2000 feet or so of outcrop of the latter. When this seam is closely examined, it is seen that narrow bands rich in carnotite alternate with green bands carrying mostly roscoelite. There is also usually present a seam generally about an eighth of an inch in thickness (though often thicker) which is almost wholly quartz. The microscope shows it to be a true quartzite, in which the original rounded detrital grains of quartz have been cemented by fresh quartz in optical continuity with the older granules. A similar quartzite occurs in the green vanadiferous sandstone above the carnotite, where it forms concretionary knots and nodules. It was not noted in the buff sandstone however, where the cementing material is calcite.

Immediately below the carnotite seam there is a parting or "floor" in the sandstone, probably originally a very thin layer of shale, which forms the working floor of the tunnel. The sandstone below this floor is plainly impregnated for a short distance with roscoelite, but the thin shale seam is regarded as the practical bottom of the deposit.

The questions of the origin and actual extent of this deposit are closely related, and of much interest. Their discussion will be deferred until the other deposits visited have been described.

Some distance below the Placerville vanadium deposit, sandstone, presumably belonging to the Dolores formation, was observed to be colored green, of a somewhat brighter hue than the vanadiferous sandstone higher up the slope. As there are some copper prospects near by, from which ore has been taken, this was supposed to be a copper stain. Qualitative tests by Dr. Hillebrand show however that the color is due to a compound of chromium.

Similar green sandstones occur on the western side of Sinbad Valley in what is apparently the La Plata formation, and were originally supposed to be impregnated with roscoelite. Dr. Hillebrand's investigations, however, show that they too owe

their color to some chromium mineral. These occurrences are interesting as showing that a green color in sandstones may result from various causes, and that even a bright green tint cannot be taken as an infallible indication of copper.

The La Sal Creek deposits.—These occur in the extreme western portion of Montrose County, southwest of Paradox, and about six miles up La Sal Creek from Cashin P. O. They are reached by trails from Paradox Valley and from Cashin. The deposits are on the south side of La Sal Creek and about 700 feet above the stream. They occur for a distance estimated at more than a quarter of a mile, along the sandstone cliffs which descend from the mesa into the cañon of La Sal Creek, and only a few feet below the level of the mesa surface.

In the absence of continuous stratigraphic work, it is impossible to correlate certainly and finally the rocks on La Sal Creek with the divisions established by Cross and Spencer in the Telluride quadrangle to the eastward. It seems probable, however, that the La Plata sandstone attains a much greater thickness in this portion of western Colorado than it does between Telluride and Placerville. The limestone bed, so characteristic a feature of the formation near Placerville and further east, is not uniformly present in this western region, and the La Plata sandstone (Variegated Beds, in part, of the Hayden Survey) is not always readily differentiated from the underlying Dolores formation (Red Beds). For a vertical distance of about 400 feet above the bed of La Sal Creek the rock is a heavy-bedded, rather fine-grained, light-colored sandstone, which is considered by Dr. Spencer to be the La Plata. Above this come thinner-bedded sandstones, with some conglomerates and shales, which are included in the McElmo formation. It is in this upper series that the uraniferous deposits occur. All the beds are here approximately horizontal.

As revealed by numerous small openings near the crest of the bluff, the carnotite, which is the material here sought, is found chiefly in a massive bed of nearly white sandstone. Some of the ore, however, lies between the sandstone and a lower bed of light-gray shale. Although the prospecting openings all lie at about the same level along the cliffs, the deposit is not nearly so regular as the vanadiferous band near Placerville.

The carnotite of La Sal Creek occurs as irregular, bunchy "pockets" in the sandstone, or along the contact of the sandstone with the underlying shale. These have all the appearance of being impregnation deposits, the solutions carrying the uranium compounds having deposited the ore wherever they found ready passage through the rock—usually along bedding planes. No roscoelite was detected with the carnotite.

The most remarkable and interesting fact in regard to the La Sal Creek deposits is their very superficial character. The ore bodies are usually flat-lying streaks, a few inches thick, which grade above and below into the common light-buff sandstone, and which die out and disappear when followed into the hillside. In tunnels run but a few feet underground the yellow impregnation of carnotite can be seen to gradually die out, to be succeeded by light-colored sandstone, showing no apparent trace of the mineral. It is doubtful whether any appreciable quantity of carnotite occurs as much as 20 feet from the surface, on any of the locations, although this distance is given from memory and not from measurements on the ground. As before stated, the impregnation has usually taken place along bedding planes; it has also proceeded along surfaces of minor and superficial movement in the rocks. In one case it was observed that a portion of the overlying sandstone had moved upon the underlying shales, the disturbance being apparently a superficial one, of a kind commonly enough observed where massive beds rest on yielding shales on a steep hillside. In other words, the movement appeared to be directly related to the present topography. The deposition of carnotite was here plainly subsequent to the movement and had taken advantage of the small openings and dislocations in the shale afforded by this very recent disturbance. It was reported that some of the best nests of ore had been found in "slide rock," i. e., rock which had slipped to same extent down the slope; but I was unable to verify this statement further than is indicated in the preceding description. There can be little doubt but that the deposits of carnotite on La Sal Creek are not only very superficial in character but very recent in age.

The Roc Creek Deposit.—The principal claim is the Copper Prince, owned by J. R. Duling, on the north side of Roc Creek, 3 or 4 miles above its mouth, and near the foot of the Miller trail to Paradox. It is reached by this trail from Paradox Valley, or by trail from Hydraulic on the Dolores River. This deposit is in the La Plata sandstone according to Dr. Spencer's observations, and has been more extensively exploited than any other seen. The sandstone, which at this point is nearly horizontal, is cut by an east and west fault, the fault plane dipping north at about 70°. The amount and character of the throw could not be determined. It is probably less than 50 feet. The carnotite occurs in the hanging wall of the fissure as small irregular branches in a loose mass of crushed sandstone and also as an impregnation of some of the firmer portions of the bed. No roscoelite was seen. Several small tunnels have been run in on the hanging wall side of the fissure (which itself carries no vein or ore-body), but they had

been securely closed by planking, and no examination of their inner ends could be made. I am thus unable to tell what becomes of the deposit as it is followed in from the surface. A few hundred pounds of picked carnotite ore has been shipped from this claim and is reported to have sold for $1.25 a pound in Denver. The character of this deposit is similar to others examined, except that in this case a well-defined fault has provided a zone of crushed and porous rock in the hanging wall, along which impregnation could take place. A few hundred feet farther west the crushed sandstone adjoining the fault has been impregnated with cupriferous solutions and is spotted with stains of the blue and green carbonates of copper.

Other Deposits.—It is known that several carnotite claims have been taken up in Gypsum Valley in what is known as the Disappointment District. The impregnated sandstone is said to cap a hill and to constitute an extensive deposit, but it was not visited. Carnotite is also reported from the Blue Mountain District, but I have no personal knowledge of these occurrences. It seems highly probable that the material will be found widely distributed in the Mesozoic sandstones of western Colorado and eastern Utah, although perhaps nowhere in very extensive bodies.

Origin of Deposits.—That the deposits of carnotite and roscoelite were formed subsequently to the deposition of the sandstones is evident from the facts presented in the preceding pages. It is equally plain that the minerals could not have resulted from the alteration, in place, of other compounds of vanadium and uranium originally deposited with the sands. The shape and position of the deposits indicate clearly that the ores have been deposited in their present position only after transportation from a greater or less distance. Moreover, the recency of the deposits and the fact that they are sometimes directly connected with faults and dislocations in the sandstones shows that the vanadium and uranium compounds could not have been the original cementing material of the quartz grains, but have in all probability locally replaced the calcite which acts as matrix to the ordinary light-colored sandstone in which the ore-bodies occur. The deposits of roscoelite appear to be comparable to the impregnations of the sandstones with cupriferous solutions observed in many places in this region, particularly on La Sal Creek near Cashin and in Sinbad Valley, whereby the sandstone becomes colored bright green with the carbonate of copper. In these cases, however, the copper appears to have been previously deposited in part as chalcocite. An analogy might also be drawn with the green chromiferous sandstone near Placerville already referred to. In all these cases the actual sources of the materials which have

been deposited by solutions in their present position are not known. Dr. Hillebrand has shown,* however, that vanadium in small amounts is widely distributed in sandstones, limestones, and igneous rocks. It is perhaps present in very small amounts in the bulk of the sandstone, and the deposits described may simply represent a concentration of this material under certain favorable conditions of solution and re-deposition.

In the absence of exploitation it is manifestly impossible to predict the probable shape and size of ore-bodies formed in this manner. The roscoelite as seen near Placerville appears, however, to be much more persistent than the carnotite. There is no apparent reason why a mass of sandstone, impregnated with roscoelite, which is continuously exposed for several hundred feet along a cliff, should not extend for a considerable distance inward from the cliff face. The carnotite, on the other hand, appears to be a much more superficial occurrence and, in fact, to have a not yet fully understood connection with the present surface of the ground. This would indicate that the carnotite results from a local concentration of material already existent in the sandstone, and the deposition of this material in the form of carnotite under conditions determined by proximity to the surface, and probably partly dependent upon a semi-arid climate.

Chemical Analyses and Discussion.

W. F. HILLEBRAND.

I. *The Green Coloring Constituent of the Placerville Sandstone.*

As noted by Mr. Ransome, the greener the sandstone, the greater has been the replacement of the calcareous cementing material by the crystalline vanadiferous mineral. Fortunately the greenest available specimen was entirely free from carbonate, and this was used for analysis, 10 grams being taken for the main portion.

The green substance was but slightly attacked by cold acids and not rapidly by hot ones; nevertheless after 12–24 hours digestion on the water-bath with diluted nitric acid, the greenish color had been transferred to the liquid, the residue of sand was nearly white, and a rather voluminous separation of non-gelatinous silica had taken place. The filtration and washing of the insoluble matter was accomplished without difficulty. The free silica in it was extracted by two or three digestions of 15 minutes each on the water-bath with sodium carbonate solution of 5 per cent strength. The flocculent matter had entirely disappeared and the sandy residue was collected in a

* This Journal, IV, vol. vi, pp. 209–216, 1898.

Gooch crucible and washed with hot sodium carbonate solution, followed by very dilute nitric acid and finally by alcohol to prevent turbid filtration. Drying of the sand was effected by allowing the pump to draw air through the crucible until no further loss in weight resulted.

The water in the sand was then determined at 105°, at 300° and above 300°. Similar water determinations having been made on the unattacked substance, the differences gave the water expelled at those temperatures from the soluble part.

The sodium carbonate solution was acidified, evaporated, and filtered, and the filtrate again evaporated, to recover the last of the silica. To this was added a very small portion which the nitric acid extract of the sandstone held in solution. The sum represents the total silica of the decomposed portion of the sandstone.

The further analysis of the nitric solution presented difficulty because of the vanadium it contained. It was carried out in a variety of ways, of which the following seemed to be most satisfactory.

Barium was first precipitated by sulphuric acid and subsequently separated from traces of lead, calcium and vanadium. Hydrogen sulphide then threw out further traces of lead and copper with much sulphur from reduction of V_2O_5 to V_2O_4. After evaporation of the filtrate to reoxidize vanadium and iron, the alumina, iron and trace of uranium with much vanadium were separated from calcium, magnesium and alkalies by three precipitations by ammonia solution. The combined filtrates were evaporated, ignited, the residue transferred to a porcelain boat with nitric acid, evaporated therein to complete dryness, and exposed in a glass tube to a current of dry hydrochloric acid gas, as recommended by Smith and Hibbs* for the expulsion of vanadium from alkaline vanadates. The removal of vanadium being incomplete, the contents of the boat were again evaporated with nitric acid and again distilled, and these operations were repeated till no further evidence of a brown distillate appeared. The boat now contained only magnesium and alkalies with a little calcium. The distillates, containing all the vanadium that was in the boat, had been collected in U-tubes charged with water, and were eventually obtained in sulphuric solution for further treatment by evaporating with sulphuric acid in porcelain.

The precipitate of Al_2O_3, etc., was dissolved in nitric acid, evaporated almost to dryness in platinum and boiled with sodium hydroxide solution. These operations were repeated on the precipitate after filtration. The iron and titanium thus

*Jour. Am. Chem. Soc., xvi, 578, 1894.

purified were redissolved, precipitated by ammonia, weighed, redissolved by acid potassium sulphate, the ferric iron was reduced by hydrogen sulphide and titrated with permanganate after boiling out the reducing agent. The titanium was then found colorimetrically by hydrogen peroxide.

The combined alkaline filtrates were heated with excess of ammonium nitrate to separate alumina from most of the vanadium. The precipitate was redissolved in nitric acid, reprecipitated by ammonia, then ignited and weighed and redissolved by acid potassium sulphate. The sulphuric solution was reduced by hydrogen sulphide, boiled and filtered from platinum sulphide, again boiled in a current of carbon dioxide and titrated hot with permanganate. Sulphur dioxide gas was then introduced, boiled out in a current of carbon dioxide, and the titration repeated, this second result being taken as representing the V_2O_4 equivalent to the V_2O_5 that still contaminated the Al_2O_3. Deducting the V_2O_4 thus found from the combined weight of Al_2O_3 and V_2O_4 gave the Al_2O_3 of the soluble constituent of the sandstone.

The combined filtrates from the alumina were evaporated, ignited to remove ammoniacal salts, the residue converted to sulphates, and united with the earlier solution of vanadium sulphate. The vanadium in it was then determined precisely in the manner already described, and when added to that found with the alumina and calculated to V_2O_5, gave the total in the sandstone.

A check was made by dissolving the sandstone in hydrofluoric and sulphuric acids in a current of carbon dioxide and titrating the V_2O_4 with permanganate. The figure thus obtained was a trifle below that found as above detailed, and this is to be attributed to the presence of a very little vanadium as V_2O_5 in carnotite, and probably as a lead vanadate. All the uranium and most of the trifling amount of lead could be extracted by cold dilute nitric acid, thus showing them to be foreign to the green substance.

It is preferable to regard iron as in the ferric state rather than as ferrous, otherwise an equivalent amount of vanadium would have to be considered as V_2O_5, for which there is no occasion. It is quite possible that the iron is in part, if not wholly, foreign to the green matter, for it would be surprising to find an exposed sandstone free from ferric oxide.

If the iron is disregarded as probably extraneous, the ratios given below afford the following empirical formula:

$$H_{396}\ R'_{194}\ R''_{39}\ R'''_{610}\ Si_{762}\ O_{2776}.$$

$$\text{or } H_{396}\ R'_{194}\ R''_{39}\ R'''_{610}\ (SiO_4)_{555}\ (Si_2O_5)_{69}.$$

Simplified this is $H_{40}\ R'_{20}\ R''_{4}\ R'''_{61}\ X_{82.5}$.

Considering that the mineral is probably not perfectly pure and the uncertainties affecting the amount of water to be considered, etc., the above affords a close approach to the typical phengitic muscovite formula $H_2KR'''_3X_3$ in which X comprises the groups SiO_4 and Si_2O_5.

Analysis of the vanadiferous sandstone.

		Sandstone. Per cent.	Ratios.		Silicate. Per cent.	Roscoelite.
Soluble in Nitric acid.	SiO_2	12·56	·763		46·06	45·17
	TiO_2	·02				·78
	V_2O_3	3·50*	·0846	·305	12·84	24·01
	Al_2O_3	6·15	·2206		22·55	11·54
	Fe_2O_3	·20	·0046		·73	FeO 1·60
	CaO	·12	·0078	·039	·44	
	BaO	·37	·0088		1·35	
	MgO	·25	·0228		·92	1·64
	K_2O	2·41	·0938	·097	8·84	10·37
	Na_2O	·06	·0035		·22	·06
	H_2O at 105°	·54	·1100		1·98	·40
	H_2O 105°–300°	·14	·0283		·51	·17
	H_2O above 300°	·97	·1978	·198	3·56	4·12
	UO_3	·05				
	PbO	·06			100·00	99·86
	V_2O_5	·05				
Insoluble in Nitric acid.	Quartz, etc.	72·24†				
	H_2O at 105°	·04				
	H_2O above 105°	·20				
		99·93				

Traces of Li, Cu, Mo, Bi. No Cl, SO_3, or P_2O_5.

An attempt to satisfactorily distribute the constituents among different chemical molecules would be futile, since, for instance, we do not know whether to ascribe the barium to a biotite or muscovite molecule, but the close approach to the muscovite ratio leaves little room to doubt the character of the body. Notwithstanding the chloritic aspect of the mineral under the microscope, the analysis shows that it cannot be a chlorite, and we have undoubtedly to do with a body closely related to the mica roscoelite, wherein, however, the percentage proportions of Al_2O_3 and V_2O_3 are reversed, thus affording a further striking example of the mutual replaceability of these two oxides.

* Oxidation by permanganate of the HFl and H_2SO_4 solution of the sandstone indicated 3·43 per cent V_2O_3 (mean of 3·50, 3·32, 3·48, 3·43).

† Containing about 65 per cent SiO_2, 7 per cent Al_2O_3 (Fe_2O_3, TiO_2) and about 0·3 per cent of zircon and other minerals not decomposed by repeated evaporations with HFl and H_2SO_4.

For comparison, the latest analysis of roscoelite from Placerville, Calif., is given a place in the above table. Peculiar, though unimportant, is the coincidence that the only two known localities for this mineral should bear the name Placerville.

II. *Green Sandstone Colored by Chromium.*

Other sandstones much brighter green than the vanadiferous one were observed and collected by Dr. Ransome, both at Placerville and 60 miles distant in Sinbad Valley. The color suggested a salt of copper as its cause, but analysis showed it to be due to chromium. Time has failed for an examination as to the nature of this coloring body. It is very difficultly soluble, thus presenting greater hindrance to analysis than was the case with the vanadium compound. It would be interesting to find it to be a micaceous mineral analogous to the one just described. Under the microscope it presents a chloritic appearance (Ransome). If opportunity offers, the problem of its nature may yet be attacked.

In still another greenish sandstone from the west bank of the Dolores River, near the mouth of La Sal Creek, analysis failed to show either vanadium or chromium.

III. *The Carnotite Ores.*

Optical Examination.—Dr. Geo. P. Merrill has kindly submitted the following notes.

"The carnotite powder appears under the microscope in the form of exceedingly minute dust-like particles, without crystal outlines and acting so faintly on polarized light as to at first seem almost amorphous. Much of the matter appears merely as a fine brownish clay, stained yellow by an amorphous pigment, but occasionally a well-defined fragment of a light yellow, translucent mineral is met with which doubtless represents the vanadium compound in its condition of ideal purity.

Working over a considerable amount of the powder, I have found occasional clusters of this yellow mineral in the form of flattened radiating crystals with pyramidal terminations which are without evident pleochroism, polarize only in dull colors, and give extinctions always parallel to the axis of elongation. These are so minute (not over $0{\cdot}25^{mm}$ in length) and so thin that I have never been able to find a crystal so oriented as to give an opportunity of determining its exact character, and I can only say that the general shape is such as to suggest a hexagonal mineral, though this is by no means certain."

Chemical Examination of the Carnotite Ores.—The chemical problems involved in the analysis of the carnotite ores were peculiarly intricate. Ideal material was quite unobtainable

and mechanical separation impossible. The first specimen received happened to be of a higher grade than any of the subsequent ones, containing about 5 per cent of sand grains and showing only very faint delicate reddish tracings indicative of some foreign iron mineral. In mass it was of a beautiful canary-yellow color and easily broken down by pressure. Other specimens were more coherent, the degree depending altogether on the extent to which the sandstone had been impregnated and altered, and they sometimes showed more of the peculiar reddish admixture.

A fact only suspected in making the first analysis was confirmed by subsequent work on lower grade ores, namely, that the vanadium existed in two conditions, in entirely distinct minerals; the greater part by far as pentavalent vanadium in the easily soluble carnotite, and a smaller, much less soluble portion, almost vanishing in the purest ores, in the trivalent state as a constituent of a silicate free from uranium. This observation explained the statement of Messrs. Poulot and Voillequé that they had found the low grade ores to be relatively richer in vanadium as compared with uranium than the high grade ores.

While the carnotite dissolves at once in cold dilute nitric acid, unfortunately the vanadiferous silicate is not quite insoluble, hence arose an important difficulty in the way of arriving at the true composition of the carnotite. It is true that in one case the silicate has been analyzed (p. 143), but it would be unsafe to correct the carnotite analysis on that basis. Moreover, the analyses were not all made on the same plan; some are less complete than others; they cannot in some respects be rigidly compared with each other.

As to the carrying out of the analysis, various procedures were tried and no one found which gave altogether satisfactory results as to each constituent, though many could be determined with the usual degree of accuracy. The difficulty was mainly due to vanadium and the small amount of phosphoric acid usually present. These two constituents were likely to be found in different precipitates and could not be separated from them at one stroke. Their complete removal from other bodies was at times impossible and the weight of the latter had then to be corrected for these residual amounts.

Two entirely different lines of attack were open. One, that of Friedel and Cumenge, described in their paper on carnotite, had already been used with apparent success. It depends on rendering the vanadium insoluble in water by evaporating the nitric acid solution to dryness. Water extracts the alkalies and uranium without dissolving the vanadium, iron, or aluminum. Repetition of this process yielded Friedel and Cumenge satis-

factory results. They recommended washing with water containing ammonium nitrate.

The other method contemplated the quantitative removal of vanadium by dry hydrochloric acid gas as already described (p. 131). This had been shown to be perfect for alkaline pyrovanadates by Smith and Hibbs and it was hoped might succeed even with such complex mixtures as the present. The distillations were made on the crude ore and also on the nitric acid solution after filtration from the insoluble matter and evaporation to thorough dryness. The action is immediate in the cold, copious red-brown vapors coming off and condensing in part as a dark red liquid in the tube. But repeated distillations and the application of heat were required to effect complete removal of the vanadium accompanied by the arsenic and molybdenum. After each distillation the contents of the boat had to be evaporated with nitric acid. The blue and green colorations apparent on adding this acid showed that the hydrochloric acid gas had reduced a good deal of the vanadium to a lower state of valence, and in this condition it was incapable of forming the volatile body.

A somewhat more satisfactory separation sometimes resulted when this distillation method was combined with that of Friedel and Cumenge by subjecting both the evaporated uranium nitrate solution and the residue insoluble in water to the action of hydrochloric acid gas.

The distillates obtained by either way were evaporated with sulphuric acid, the arsenic and molybdenum were separated by hydrogen sulphide, and the vanadium was then titrated by permanganate at a temperature near boiling and again after reduction by sulphur dioxide gas. In one or two cases when the temperature of distillation had been high and it was feared some iron had passed over, the distillates were evaporated in porcelain with nitric acid, transferred to a platinum crucible, evaporated therein with sulphuric acid and fused with sodium carbonate. The aqueous extract was then treated as above for arsenic, molybdenum and vanadium.

The separation of Friedel and Cumenge, while perhaps adequate for technical purposes in ores free from phosphorus,* does not in my hands give perfect satisfaction even then. It is impossible to prevent a little of the vanadium, also of the iron and aluminum, from going with the uranium, and on the other hand a little uranium may stay with the vanadium.

* With even only half a per cent of P_2O_5 many times that amount of UO_3 is rendered insoluble in water after evaporation to dryness with nitric acid. The compound formed is of a lemon-yellow color, which is masked by the separated vanadic acid until this has been removed by ammonia. This insoluble body was treated as follows in order to arrive at the P_2O_5 and UO_3 it contained. After solution in nitric acid the phosphorus was precipitated by ammonium molybdate, and from the filtrate the uranium by three precipitations by ammonia.

Again when the vanadic acid is extracted from the residue by ammonia, as prescribed by Friedel and Cumenge, a little of the other constituents of the residue accompany the vanadium into solution.

If the combination of the two methods is used, it is better after removal of the vanadium by distillation to further treat the two residues separately at first instead of to unite them at once. Full details of this treatment are unnecessary and would unduly extend this paper. Suffice it to say that from the uranium portion the little iron and aluminum present are separated by ammonium sulphide and carbonate, and after removal of the latter, and acidification, the uranium can be thrown down by ammonium sulphide, and then by at least two precipitations by ammonia, or far better, by precipitating the neutral hydrochloric solution by freshly precipitated and alkali-free mercuric oxide at boiling heat, as prescribed by Alibegoff.* As pointed out by von Foullon and also by Alibegoff, contrary to certain still widely disseminated statements, ammonium sulphide does not afford a good separation of uranium from calcium. This is perhaps especially true if the solution contains any phosphorus. Again, contrary to another statement, it seems perfectly possible to separate uranium completely from alkalies by a few ammonia precipitations.

The finally ignited and weighed U_3O_8 was redissolved in nitric acid, filtered if necessary (SiO_2, Al_2O_3, Fe_2O_3), and divided into two parts of which the one was tested for the very little P_2O_5 usually present, and the other for vanadium by conversion into sulphate, reduction by sulphur dioxide gas, and titration by very dilute permanganate solution.

Table of Analyses of Carnotite Ores.

I. Copper Prince Claim, Roc Creek, Montrose Co., Colo.

According to the donor of the specimen, Mr. J. R. Duling, I-*a* is from the same lot as that from which Mr. Poulot obtained the specimens afterwards analyzed by Friedel and Cumenge.

II. Yellow Boy Claim, La Sal Creek, Montrose Co., Colo.
III. Yellow Bird Claim, La Sal Creek, Montrose Co., Colo.

The last two claims belong to the same group and the ore is from the same "blanket" (Voillequé).

I-*b* and II-*b*, the first analyses made, are not strictly comparable with the other analyses since they represent the effect of warm dilute hydrochloric acid, whose greater action is shown by the nearly complete solution of the ferruginous admixture. Cold, dilute nitric acid was used for the other analyses.

* Ann. Chem. u. Phar., vol. ccxxxiii, 133, 1886; Zeit. für anal. Chemie, xxvi, 632, 1887.

	I.			II.			III.
	a	*b*	*c*	*a*	*b*		
Insol.	7·10*	8·34†	19·00‡	10·33§	‖		¶
UO_3	54·89	52·25	47·42	54·00	52·28		20·51
V_2O_5	18·49	18·35	15·76	18·05	17·50		7·20
P_2O_5	·80	·35	·40	·05	tr.		none
As_2O_5	tr.	·25	none	none	none		none
Al_2O_3	·09	?	·08	·29	?		·08?
Fe_2O_3	·21	1·77	·72	·42	3·36		·25
CaO	3·34	2·85	2·57	1·86	1·85		1·64
SrO	·02	?	?	tr.	tr.		?
BaO	·90	·72	·65	2·83	3·21		·29
MgO	·22	·20	·24	·14	·17		·07
K_2O	6·52	6·73	6·57	5·46	5·11		1·51
Na_2O	·14	·09	·07	·13	·02?		·01
Li_2O	tr.	?	?	tr.	?		?
H_2O 105°	2·43	2·59	1·85	3·16	4·52	total	1·85
H_2O 350°	2·11	3·06	2·79	2·21	3·49	H_2O in ore	1·64 (300°)
$H_2O+350°$	none	none	none	none			·19(+300°)
PbO	·13	·25	·18	·07			·09
CuO	·15	·20	·22	tr.			tr.
SO_3	none	·12	·18	none			none
MoO_3	·18	·23	·18	·05			·04
SiO_2	·15	·06	·13	·20			·07
TiO_2	·03	·10	?	?			·06?
CO_2	·56	·33	none	none			
	98·46	98·84	99·01	99·25			

* Containing ·54H_2O, ·09V_2O_5.

† The insoluble matter had the following composition: SiO_2 5·18, V_2O_5 ·21, P_2O_5 ·09, K_2O ·26, Na_2O ·04, H_2O (105°) ·56, (350°) ·32 (+350°) ·48, Al_2O_3, TiO_2, Cr_2O_3, etc, by diff. 1·20. The SO_3 of this analysis is not combined with BaO, for it is wholly extracted by dilute acids. Once in solution the acid used is sufficient to prevent its immediate precipitation as $BaSO_4$ by union with some of the barium present. The same holds true for the SO_3 of I-*c*.

‡ This material was obtained by floating off the finer matter, allowing it to settle, collecting on a Gooch filter, and drying it in a current of air drawn through the crucible. The insoluble matter held in addition to 16·41 quartz and silicates including ·39 V_2O_5 and a little UO_3), H_2O (105°) ·83, (300°) ·73, (+300°) 1·03; total H_2O 2·59.

§ Containing ·16 V_2O_5 and 1·90 H_2O.

‖ The insoluble matter contained besides quartz and silicates ·25 V_2O_5, ·21K_2O, ·05 Na_2O.

¶ This analysis was made purposely on a relatively poor ore, furnished by Messrs Poulot and Voillequé, with the object of determining, if possible, the composition of the vanadiferous silicate which it contained (see p. 143). The data for calculating the H_2O values of both analyses are as follows:

	Ore. (*a*)	After extraction of carnotite by cold, dilute nitric acid. (*b*)	After extraction of residue by hot nitric acid, sod. carb., etc. (*c*)
H_2O 105°	3·53	1·68	·02
H_2O 300°	2·11	·47	·03
$H_2O+300°$	·83	·64	·02
	6·47	2·79	·07

a–*b* furnishes the values for the carnotite as shown in analysis III; *b*–*c* gives those for the less soluble silicate (p. 143).

Discussion of the Carnotite Analyses.—It will be noted that a somewhat marked deficiency appears in most of the analyses, the cause of which is quite unknown. Great care was exercised in most cases and especially in those which show the greatest loss. It seems hardly possible that any serious constant loss of a known constituent should have occurred, but the only alternative demands the presence of an element or elements unnoticed and which cannot have been weighed with the known constituents. The researches of M. and Mme. Curie have shown that these ores contain traces of radio-active elements, precipitated the one by hydrogen sulphide, the other by sulphuric acid. Their presence, however, in quantity sufficient to account for the observed losses in the above analyses, especially when 10 grams of ore were operated on, could not possibly have escaped observation. To whatever cause it may be due, this loss alone suffices to render somewhat uncertain any calculations based on the analytical figures, though if the loss is to be ascribed to uranium or vanadium the ratios would not be sufficiently affected to obscure any simple relations that might exist.*

Another difficulty is the impossibility of knowing what constituents to exclude and what to include in deducing molecular ratios. It is certain that most if not all of the iron is foreign to the yellow body. It is probable that phosphorus is likewise so, since its extraction by dilute acids does not keep pace with that of the uranium and vanadium. It may possibly be in combination with the iron, in part at least. The alumina doubtless is derived from the vanadiferous silicate which seems to exist in all the ores and which is not quite insoluble in cold dilute acids. If so, a small portion of the vanadium, potassium, magnesium, and water are to be attributed to this mineral, but a general correction based on the analysis of this compound (see p. 143) would not be justifiable. Its application leads to nothing definite, even in the case of the particular ore No. III, from which the silicate analyzed was derived.

In the following tables are given first the recalculated analyses and then the molecular ratios. All those constituents have been excluded which pretty certainly do not belong to the carnotite, but small portions of some of those retained are unquestionably extraneous. In two cases (I-*a* and I-*b*) a certain proportion of lime has been arbitrarily excluded equivalent to

* According to Dr. Harry C. Jones of Johns Hopkins University, who very kindly undertook to examine a specimen of the Copper Prince ore for rare gaseous elements, helium is not present. Faint hydrogen lines were observed, the source of which was ascribed to water vapor. Other lines, due probably to hydrocarbons, were fairly strong, but the specimen had been long enough exposed in our laboratory and elsewhere to have accumulated enough dust to account for them.

the acid anhydrides CO_2, MoO_3, and SO_3, less what is needed to offset PbO and CuO.

Carnotite Analyses Recalculated.

	I-*a*	I-*b*	I-*c*	II-*a*	II-*b*	III
V_2O_5	20·72	21·09	20·12	20·54	19·85	20·62
P_2O_5	·90	·40	·51	·06		
As_2O_5		·29				
UO_3	61·53	60·06	60·55	61·44	59·31	58·75
CaO	3·03	2·77	3·28	2·11	2·10	4·70
BaO(SrO)	1·03	·83	·83	3·22	3·64	·83
MgO	·25	·23	·31	·16	·19	·20
K_2O	7·31	7·73	8·39	6·21	5·80	4·33
Na_2O	·15	·10	·09	·15	·02	·03
$H_2O-105°$	2·72	2·98	2·36	3·59	5·13	5·30
$H_2O+105°$	2·36	3·52	3·56	2·52	3·96	5·24
	100·00	100·00	100·00	100·00	100·00	100·00

Ratios.

	I-*a*		I-*b*		I-*c*		II-*a*		II-*b*		III	
V_2O_5	1133	1196	1208	1248	1101	1137	1124	1128	1081		1128	
P_2O_5	63		28		36		4					
As_2O_5			12									
UO_3	2140		2088		2105		2136		2062		2043	
CaO	541	671	495	606	586	718	377	627	375	660	839	943
BaO(SrO)	68		54		54		210		238		54	
MgO	62		57		78		40		47		50	
K_2O	776	809	826	848	891	911	659	692	616	620	460	466
Na_2O	33		22		20		33		4		6	
$H_2O-105°$	1511		1656		1311		1994		2850		2944	
$H_2O+105°$	1311		1956		1978		1400		2200		2911	

These ratios lead to the following empirical formulas, in which only the water given off above 105° is considered. Since the water is wholly removable below 350° it is regarded as water of crystallization and not of constitution.

	R′	R″	R^v	U	O	H_2O
I-*a*	1618	671	2392	2140	13880	1311
I-*b*	1696	606	2496	2088	13958	1956
I-*c*	1822	718	2274	2105	13629	1978
II-*a*	1384	627	2256	2136	13367	1400
II-*b*	1240	660	2162	2062	12871	2200
III	932	943	2256	2043	13178	2911

If it be assumed that the bivalent elements offer the most accurate determinations, the above ratios may be reduced to the following simpler terms on that basis:

	R′	R″	R^v	U	O	H_2O
I-*a*	2·41	1	3·56	3·19	20·68	1·95
I-*b*	2·80	1	4·12	3·45	23·03	3·23
I-*c*	2·54	1	3·17	2·93	18·98	2·75
II-*a*	2·21	1	3·60	3·41	21·32	2·23
II-*b*	1·88	1	3·27	3·12	19·50	3·33
III	·99	1	2·39	2·16	13·98	3·09

The results, however, show a great lack of agreement and wide variation. It is plain that no probable formula can be calculated for the yellow body. The variations are of such a nature as to indicate in the plainest manner that it is a mixture of several substances.

Such a detailed discussion as the foregoing would hardly have been justified in view of the negative conclusions arrived at, but for the fact that Messrs. Friedel and Cumenge in their paper announced a simple formula for the body examined by them and gave it the specific name carnotite. Their published analyses are as given below, from which they have excluded considerable sand and traces of barium, aluminum, lead, copper, and radio-active bodies as present in excessively small quantities. They make no mention of calcium, and admit that their values for water are open to doubt. The formula deduced by them is $2U_2O_5$,* V_2O_5, K_2O, $3H_2O$.

Analyses of Carnotite by Friedel and Cumenge.

	Found.				Calculated.
U_2O_5*	64·70	62·46			63·54
V_2O_5	20·31	19·95			20·12
K_2O	10·97	11·09			10·37
H_2O			5·29	·481	5·95
Fe_2O_3	·96	·65			
					99·98

It appears from these analyses that Messrs. F. and C. by great good fortune obtained a variety of samples of the pure potassium compound, free from calcium and without appreciable admixture of barium. This is very remarkable in view of the fact that all the ores from different localities examined by me show large admixture of calcium or barium salts or both, even that which is certified to have come from the same lot as that from which their material was taken. The French authors give a brief outline of their methods of analysis. That one which afforded them the best results would involve the weighing of any calcium present as sulphate along with the potassium, on the assumption that the presence of that element had been overlooked. It is much to be desired that a re-analysis of their material should be made, if there is any of it still available, in order to clear up the doubt connected with the first analysis.

In the light of the evidence herein set forth, the existence of a distinct mineral species having the composition claimed for carnotite can by no means be considered as established.

* Old notation equivalent to the modern UO_3.

Average quality of marketed ore.—As these carnotite ore bodies are being exploited for the market, it is of some interest to know the average quality of each commercial lot. A carefully prepared sample representing several tons of ore was received from one of the commercial houses of Denver and was found to carry 11·49 per cent of uranium counted as U_3O_8, and 6·40 per cent of vanadium counted as V_2O_5. Over one-sixth of the vanadium existed, however, in the trivalent state, not as a constituent of the yellow body, but doubtless of a silicate like the one whose composition is given on p. 143.

Commercial assay.—The commercial assay of these ores has presented difficulties to the technical chemist, the results being sometimes very discordant.

As to uranium this is not surprising. The methods that have probably been commonly employed will give varying results according to the contents of the ore in phosphorus and alkaline earths. Possibly the old Patera process, described in most text-books on analytical chemistry, might be made to serve, with modifications called for by the large amount of vanadium present.

The assay for vanadium presents little difficulty and does not require much time. The ore is fused with sodium carbonate, leached with water and the fusion repeated on the residue. The combined filtrates are acidified by sulphuric acid, arsenic and molybdenum are precipitated in the hot solution by hydrogen sulphide, whereby the V_2O_5 is reduced to V_2O_4. After filtration and expulsion of hydrogen sulphide by boiling, the vanadium is titrated in hot solution by permanganate. It is then reduced by sulphur dioxide gas, and after boiling this out the titration is repeated. The results are exact, and they are not affected by the uranium that may be present.

IV. *Composition of the Vanadiferous Silicate in the Carnotite Ore.*

As already mentioned the ores contain a vanadiferous silicate free from uranium. To the end of ascertaining its composition if possible, ore No. III (p. 128), from the Yellow Bird claim, low in carnotite but relatively rich in vanadium, was treated as follows:

The carnotite from 10 grams was extracted by cold, dilute nitric acid, and the well washed residue, consisting of coarse sand and an utterly amorphous mud, by 4 per cent sodium carbonate solution to get rid of the small amount of silica presumably set free but not dissolved by the acid. This amounted to 0·35 per cent in duplicate determinations, and together with 0·06 per cent in the acid solution or 0·41 per cent in all, may

serve as a maximum figure by which to gauge the action of the cold acid on the silicate or silicates in the ore. The residue was then digested for several hours with warm nitric acid of about 1·2 sp. gr. until as shown by a companion test its action had ceased. It was then filtered, washed and digested with 5 per cent sodium carbonate solution to dissolve the copious deposit of silica. The final residue was collected in a Gooch crucible, washed with sodium carbonate, followed by dilute nitric acid to remove all alkali, then by alcohol to prevent turbidity in the filtrate, and dried by suction of the pump. In it the water was determined at different temperatures, also its general composition.* From the sodium carbonate filtrate the silica was obtained by two evaporations and filtrations, also the trifling amount held by the acid solution. This latter was then fully analyzed and the complete results follow.

Composition of vanadiferous silicate in carnotite ore.

	Per cent in ore.		Per cent calculated to 100.	Ratios.	
SiO_2	6·48		43·94	·7275	
Al_2O_3	2·445	(2·45 and 2·44)	16·58	·1622	
V_2O_3	·965	(·93 and 1·00)	6·54	·0434	·2426
Fe_2O_3	·875	(·87 and ·88)	5·93	·0370	
CaO	·035		·24	·0043	·1142
MgO	·654	(·652 and ·657)	4·43	·1099	
K_2O	·546		3·70	·0393	·0430
Na_2O	·03		·20	·0037	
H_2O 105° C.	1·66†		11·26	·9222	
H_2O 300° C.	·44†		2·98	·1655	
H_2O above 300° C.	·62†		4·20	·2333	
	14·75		100·00		

Also traces of titanium, manganese, and lithium.

On the improbable assumption that the iron is to be wholly included, and regarding only the water given off above 300°, the following ratios result:

$$H_{467}\,R'_{86}\,R''_{114}\,R'''_{465}\,Si_{727}\,O_{2573};$$

which become, if the iron is excluded,

$$H_{467}\,R'_{86}\,R''_{114}\,R'''_{411}\,Si_{727}\,O_{2462}.$$

These figures, while strongly suggesting definite ratios between certain of the constituents, do not under the circumstances warrant the deduction of a formula, nor do they lead

* SiO_2 48·89, Al_2O_3, Fe_2O_3, zircon etc., ·44, TiO_2 ·08, MgO ·01, K_2O ·11, Na_2O ·03, H_2O ·07; total 49·63.

† Determined on a separate portion of the same powdered sample. See p. 138 footnote for data.

to the same conclusion as in the case of the green cementing material of the Placerville sandstone. The phengite-muscovite ratio of that is not apparent here. Yet it is not at all unlikely that a mineral like the one from Placerville is present, but contaminated with some other. In fact it would be surprising to find in such thoroughly altered sandstones anything but a mixture. The fact of the existence of such vanadiferous transition products is itself highly interesting, and these tedious analyses cannot therefore be considered as made in vain. The mud-like amorphous character of this material precludes any hope of aid from the microscope in solving the question of its homogeneity.

Summary.

The body called carnotite is probably a mixture of minerals of which analysis fails to reveal the exact nature. Instead of being the pure uranyl-potassium vanadate, it is to a large extent made up of calcium and barium compounds. Intimately mixed with and entirely obscured by it is an amorphous substance—a silicate or mixture of silicates—containing vanadium in the trivalent state, probably replacing aluminum.

The deposits of carnotite, though distributed over a wide area of country, are, for the most part, if not altogether, very superficial in character and of recent origin.

The green coloring and cementing material of certain sandstones near Placerville, Col., is a crypto-crystalline alumino-vanadio-potassium silicate resembling roscoelite, but with the percentage proportions of Al_2O_3 and V_2O_3 reversed. It constitutes over 25 per cent of the sandstone at times, and contains nearly 13 per cent of V_2O_3, the latter amounting in the maximum case observed to 3·5 per cent of the sandstone.

As yet these highly vanadiferous sandstones have been found only at Placerville, where it is intended to work them for vanadium. Carnotite is associated with them in only trifling amount.

Other sandstones noticed owe their bright green color to chromium. In yet another case where the color was dull green, this was not due to either chromium or vanadium.

U. S. Geological Survey, April, 1900.

ART. XV.—*Restoration of Stylonurus Lacoanus, a Giant Arthropod from the Upper Devonian of the United States;* by CHARLES E. BEECHER. (With Plate I.)

IN the animal kingdom, the attribute of bigness has come to be regarded as one of the prerogatives of the vertebrates. On this account, invertebrates seldom receive credit for having a size of more than a fraction of a cubit, and are looked upon as objects to be held in the hand or viewed under a lens. As a matter of common experience, and probably also of congratulation, large invertebrates *are* rare, and some whole classes cannot furnish a single individual measuring more than a few inches in greatest diameter.

In a list of arthropod giants, the subject of the present note must be included, and will take equal rank with the Giant Spider-Crab of Japan (*Macrocheira Kaempferi*) and the great "Seraphim" of the Scotch quarrymen (*Pterygotus anglicus*). The former can safely claim to be the largest representative of the Brachyurans that has ever existed, and to the latter may be accorded the same distinction among the Merostomes.

The living species of the Merostomata comprise only the American and Moluccan Horse-Shoe Crabs, *Limulus polyphemus* and *L. moluccanus*. The latter sometimes attains a length of three feet, and measures eighteen inches across the carapace. To find other species in this order worthy of comparison with the huge Brachyuran of Japan, it is necessary to go back to the Paleozoic forms, and among these the larger species of *Pterygotus*, and the *Stylonurus* here noticed, fill all the requirements. It should be borne in mind, however, that these statements are based upon comparative lengths and breadths. If bulk alone were considered, the common lobster (*Homarus americanus* and *H. vulgaris*) should be mentioned, though in length and extent of limbs it would be considerably smaller.

Concerning the size of the Scotch "Seraphim," Dr. Henry Woodward[1] states that "From our present knowledge of the almost perfect remains of *Pterygotus anglicus*, and on the evidence of the numerous detached portions of this extinct genus, we are justified in concluding that it attained a length of six feet, and a breadth of nearly two feet at the widest part of its body." This huge Merostome has been found in the Lower Old Red Sandstone of Scotland, at a horizon nearly equivalent to the one furnishing the remains of *Stylonurus* in America. Thus what seem to be the two largest species of this class were contemporaries, though not associates.

Historical.

The first specimen found in America that can be referred to the genus *Stylonurus* was collected by the writer about 1870, and loaned to Professor James Hall. It remained in his hands unnoticed until 1884, when he described it as *Eurypterus Beecheri*.[4] The specimen preserves the abdomen and portions of two of the large posterior limbs. No species of *Eurypterus* known possessed such greatly elongated limb joints, and there seems to be no good reason for not referring it to *Stylonurus*, in which this is a normal character. The specimen of *Stylonurus Beecheri* is uncompressed, and apparently retains the proportions of form and convexity as in life. On this account, it was of considerable importance in the restoration of the larger species.

In 1882, Hall was furnished with a plaster cast of the carapace of a large arthropod, by Dr. Cook, then State Geologist of New Jersey. The original specimen was from the Catskill group at Andes, Delaware County, New York, and had been sent to the museum at Rutgers College, New Brunswick, New Jersey. Prof. D. S. Martin[3] made the first reference to this species in some remarks on "A New Eurypterid from the Catskill Group," before the New York Academy of Sciences, October 16, 1882, an abstract of this note appearing in the transactions of the same society some time after June, 1883. In this abstract, the species is neither described nor figured, and Hall is not mentioned in any connection. Martin states that he saw the specimen (=cast sent to Hall) in the State Museum at Albany, and it bore the name *Stylomurus excelsior* (evidently a misprint for *Stylonurus*).

The next reference to this form in point of time, and the first publication of a generic and specific name accompanied with a description and accurate illustration, was given by E. W. Claypole,[1] in a paper read before the American Philosophical Society, September 21, 1883, under the title "Note on a large Crustacean from the Catskill Group of Pennsylvania." It is stated on the signature containing this paper that it was printed November 2, 1883. Claypole's description was based upon a second specimen found in Wyoming County, Pennsylvania, which preserves about three-fourths of the cephalothorax, and belonged to the collection of R. D. Lacoe of Pittston. This was given the name *Dolichocephala Lacoana*, and rightly classified with the Merostomata. It therefore appears that, up to this time, the name *Stylonurus excelsior* was simply *nomen nudum*, and as such cannot be recognized as valid.

In 1884, Hall[2] published his description and figure of the

STYLONURUS (length nearly five feet).

New York specimen, in the thirty-sixth Annual Report of the New York State Museum, in a paper entitled "Description of a New Species of Stylonurus from the Catskill Group." It is here that the New York specimen was first figured and a description given, and the date of publication of this paper is the one to be considered in deciding the claims of *Stylonurus excelsior* as Hall's species.

At the Philadelphia meeting of the American Association for the Advancement of Science, September, 1884 (Proc. A. A. A. S., vol. xxxiii, published 1885), Hall[e] presented a note on *Stylonurus excelsior*, merely referring to its occurrence, and citing Martin's abstract with page and month of publication. This citation is repeated by Hall in each of his notices of this species, for only by thus establishing the species could he have any claim to priority. As already mentioned, Martin's paper does not attempt any description of this form, and Hall is not mentioned. Hall further says: "The carapace is described and figured in the 36th Report of the N. Y. State Museum of Natural History," without reference to plate, page, or year, and it is therefore quite possible that this description was not published until after the meeting of the Association. In any case, it appeared some months later than Claypole's paper, and the name *Dolichocephala Lacoana* has priority over *Stylonurus excelsior*, and must be recognized.

Claypole failed to point out the affinities of this form with *Stylonurus*, and proposed a new generic term for his species. Although there are differences that may prove of generic value when more complete specimens of the American species have been studied, yet at the present time there seem to be no strong reasons why the specimen in question should not be considered as belonging to *Stylonurus*, and it is upon this ground that the present restoration is attempted.

Material available for a Restoration.

Restorations of extinct organisms are largely exhibits of mental architecture, based upon the personal interpretation of a certain number of real things. Some statement, therefore, should be given of the character and amount of the material that has been collated to furnish a restoration of *Stylonurus Lacoanus*.

(1) The specimen of the cephalothorax described by Hall shows the complete outline and upper surface of this part, and a cast from the original was taken to represent this portion in the restoration. (2) The type of *S. Lacoanus* Claypole includes a large part of the cephalothorax of an individual nearly the same in size as the preceding. (3) Dr. J. M. Clarke

discovered that this specimen also preserved considerable evidence as to the nature of the appendages, and he succeeded in developing what appear to be the chelate antennæ, the first pair of gnathopods, and the mandibular bases of at least three others. (4) The length and number of joints in the limbs are taken from the English species *S. Logani* and *S. Powriei*, of which quite complete, though smaller, individuals have been described by Woodward.[10] (5) The outline and proportions of the abdomen follow closely those of the English forms and of *S. Beecheri*, the latter giving the natural convexity. (6) A portion of a large abdominal segment found by the writer in the Chemung group at Warren, Pennsylvania, and apparently belonging to a nearly related species, has an ornamentation closely approaching that on the cephalothorax of the type, and was used to elaborate the sculpture over the abdomen of the restoration. (7) The form and character of the telson spine correspond to *S. Logani* and also to some large fragments found by F. A. Randall at Warren and Ackley, Pennsylvania, in the Chemung group, and probably belonging with the abdominal somite already mentioned.

With the date furnished by the foregoing material, the restoration was undertaken. The first model in relief was constructed in clay, and from it a plaster mold was taken. A number of casts have been made since, and a photograph of one of them is represented in the accompanying plate (Plate I).

In this connection, it may be suggested that the type specimen of *Stylonurus* (?) (*Echinocaris*?) *Wrightianus* (Dawson sp.) represents two proximal joints of one of the large crawling feet of a form related to *Stylonurus*, and not two somites of the abdomen as indicated by Hall.[5] Any reference is at present somewhat uncertain, owing to lack of positive knowledge, and the fact that the specimen in question was first described as a plant (*Equisetides*[2]), then referred to the Phyllocarida (*Echinocaris*[6]), and lastly appeared as a possible Merostome, shows how this form may be interpreted by different observers. No one can doubt its arthropod nature, on account of the characteristic surface markings. Its elliptical or ovoid section without any flattening of the epimera, the very considerable overlapping of the joints, and the configuration of the suture, are more strongly indicative of the nature and requirements of a limb than of abdominal segments.

The Relief Model.

In this restoration, the animal is represented as lying on a slab, with the entire dorsal surface exposed. The cephalothorax has an axial length of 25^{cm} and a width of 22^{cm}.

The chelate antennæ were doubtless carried in a folded position, as in most related genera, and seldom were visible from the dorsal side. They are, therefore, not shown. The three pairs of short gnathopods, serving partly as swimming organs, are seen extending outward from the antero-lateral margins of the cephalothorax. Several of their distal joints are each provided with a pair of flat, ridged, spinous processes, and a similar spine at the termination of the limb.

The two pairs of great crawling feet extend outward and backward from the postero-lateral margins of the cephalothorax. The anterior pair expose 109^{cm} of length, and the posterior pair about 108^{cm}. The elements of the limbs are represented as grooved, as this character seems necessary to give the needed strength to long slender joints, and also because a similar conformation is present in *S. Beecheri*.

The abdomen measures 30^{cm} in greatest width at the fifth segment, and 66^{cm} in length exclusive of the telson. The posterior abdominal segments are represented without detachable epimera, as this feature is not as yet known to be constant for the genus, although present in some species.

The telson spine agrees proportionally in length with the same member in *S. Logani* and *S. Powriei* as described by Woodward,[10] and was given a slight upward curvature as in *Limulus*. It measures 54^{cm} in length and 7·5^{cm} across at the proximal end.

Altogether the animal as restored has a length of nearly five feet (147^{cm}), and with the legs extended it would measure about eight feet (242^{cm}) across.

It is not intended to claim any high degree of accuracy for this restoration, but merely to represent in some graphic form an animal approximating in size and character an individual of the species *Stylonurus Lacoanus*. Its size alone was the chief incentive for attempting a reconstruction, and some sacrifice of exact detail may well be allowed, in order to make any presentation of this magnificent arthropod.

Yale University Museum, New Haven, Conn., September 5, 1899.

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Art. XVI.—*The Iodometric Estimation of Arsenic Acid;* by F. A. Gooch and Julia C. Morris.

[Contributions from the Kent Laboratory of Yale University—XCVI.]

The interaction of a soluble arseniate and a soluble iodide in a suitably acidulated solution results, as is well known, in the reduction of the arsenic acid (more or less completely according to conditions of temperature and proportions of reagents and solvents) with the corresponding liberation of two atoms of iodine for every molecule of arsenic acid (H_3O_4As) reduced. Inasmuch, however, as the reaction of this process is reversible, it is necessary, in order that the reduction may be complete, to nullify the oxidizing action of the iodine liberated. Theoretically this end may be accomplished in either of two ways, by volatilizing the free iodine bodily or by destroying the oxidizing power of the iodine by converting it to hydriodic acid. The former method was followed in a process devised for the estimation of arsenic acid and elaborated in this laboratory.* This method, as originally put forward, consisted in adding to the solution of the arseniate potassium iodide in excess of the amount theoretically indicated, with 10^{cm^3} of sulphuric acid of half strength, and so arranging the dilution that the total volume of the liquid should be about 100^{cm^3}, boiling until the volume decreased to 40^{cm^3}, bleaching by the cautious addition of sulphurous acid the trace of free iodine still held by the hydriodic acids, diluting, cooling, neutralizing with acid potassium carbonate, and titrating with iodine, after adding the starch indicator. This process, depending upon the removal by volatilization of all but the last traces of liberated iodine and the conversion of this minute residue by sulphurous acid, involves no secondary reactions of a sort likely to influence the main effect. It is exact and fairly rapid.

The method of Williamson,† brought forward more recently, depends upon the conversion of the liberated iodine to hydriodic acid. The interaction at ordinary temperatures of a suitably strong acid, hydrochloric or sulphuric acid, upon the mixture of the arseniate and iodide sets free iodine, and the liberated iodine is converted to hydriodic acid by the action of sodium thiosulphate, the end point being the disappearance of the iodine color.

According to Williamson's directions, 25^{cm^3} portions of the solution of the arseniate are treated with potassium iodide and mixed with an equal volume of hydrochloric acid of sp. gr.

* Gooch and Browning, this Journal, xl (1890), 66.

† Jour. Soc. Dyers and Colorists, 1896, 86–89.

1·16. The precaution is recommended that the strength of the solution of the arseniate shall not exceed the decinormal value, in order that the dilution consequent upon titration by the thiosulphate may not be too great—the reducing action brought about by the action of the strong acid upon the arseniate and iodide being reversible upon the dilution of liquid with water. This procedure thus limits the process to the determination of about 0·18 gram of arsenic acid in 25$^{cm^3}$ of the solution to be treated with an equal volume of hydrochloric acid of sp. gr. 1·16. Obviously, however, the process should, so far as the reduction is concerned, be applicable to larger amounts of arsenic provided the strength of the acid is kept up proportionately. It is essential that the liquid at the end of the titration should contain approximately ten per cent of its mass of absolute hydrochloric acid or about one-third of its volume of the aqueous acid of sp. gr. 1·16.

The arsenic acid is measured either by the amount of standard thiosulphate required to bleach the iodine or by the amount of iodine required to reoxidize the reduced arsenious acid, after neutralizing with acid potassium carbonate. If the former alternative is followed, the end-reaction must be the disappearance of the yellow color of the iodine, since in solutions so strongly acid it is impossible to place dependence upon the starch indicator; in using the latter alternative, the starch indicator is, of course, permissible and preferable.

In the direct titration of the iodine by thiosulphate two sources of error present themselves as possibilities; first, the excessive liberation of iodine by the action of air upon the strongly acidulated iodide; and second, the liability of the thiosulphate,* if present even in momentary or local excess during the process of titration, to break down under the action of strong acid, thus changing its capacity to convert iodine to hydriodic acid. The latter contingency should be remote in proportion to the caution used in adding the thiosulphate and in keeping the liquid well stirred; the former must of necessity vary with the acidity of the solution containing the iodide, the time of exposure to atmospheric action, and the degree of contact with the air incidental to stirring. We have thought it desirable, therefore, to see how far each of these possibilities is likely to interfere in the practical conduct of an ordinary analysis.

The effects likely to result simply from the strong acidification of the solution containing potassium iodide and their variation for conditions of dilution representing the beginning and the end of a titration on the lines laid down are shown in

* Norton, this Journal, vii, 287.

the following table. The solution of potassium iodide was diluted as indicated before the addition of the acid and the iodine set free was titrated by thiosulphate.

HCl Sp. gr. 1·16 taken. cm³.	KI taken. gm.	Total volume. cm³.	$Na_2S_2O_3$ added at once. In terms of H_3O_3AsO. gm.	$Na_2S_2O_3$ added after 5 minutes. In terms of H_3O_3AsO. gm.	$Na_2S_2O_3$ added after stirring 5 minutes. In terms of H_3O_3AsO. gm.
25	2	50	0·0013		
25	2	75	0·0004		
25	2	50		0·0035	
25	2	75		0·0019	
25	2	50			0·0042
25	2	75			0·0021
50	2	100	0·0017		
50	2	150	0·0004		
50	2	100		0·0035	
50	2	150		0·0019	
50	2	100			0·0035
50	2	150			0·0014

The proportionate strength of acid and the time before titration are, obviously, the essential factors. The absolute amount of acid present and the stirring seem to make little difference.

As to the action of the hydrochloric acid on small amounts of the thiosulphate, we have the evidence of the experiments detailed in the following statements, in which 1, 2, and 5$^{cm^3}$ of nearly $\frac{n}{10}$ thiosulphate are exposed to the action of 25$^{cm^3}$ hydrochloric acid, sp. gr. 1·16, without dilution or diluted with

HCl Sp. gr. 1·16. cm³.	Volume before titration. cm³.	$Na_2S_2O_3$ nearly $\frac{n}{10}$ in terms of H_3O_3AsO. cm³.	gram.	Iodine to color without dilution in terms of H_3O_3AsO. gram.	Error of titration without dilution in terms of H_3O_3AsO. gram.	Iodine to color after diluting to 75$^{cm^3}$ in terms of H_3O_3AsO. gram.	Error of titration after dilution in terms of H_3O_3AsO. gram.
25	26	1	0·0071	0·0062	—0·0009	0·0071	0·0000
25	50	1	0·0071	0·0071	0·0000	0·0071	0·0000
25*	50	1	0·0071	0·0079	+0·0008	0·0079	+0·0008
25	50	2	0·0141	0·0146	+0·0005	0·0146	+0·0005
25*	50	2	0·0141	0·0157	+0·0016	0·0157	+0·0016
25	30	5	0·0353	0·0336	—0·0017	0·0374	+0·0024
25	50	5	0·0353	0·0359	+0·0006	0·0359	+0·0006
25*	50	5	0·0353	0·0411	+0·0058	0·0411	+0·0058

* In these experiments the acid stood in contact with the thiosulphate 5 minutes before titration.

an equal volume of water, were titrated with nearly $\frac{n}{10}$ iodine. The condition of acidity when the volume of 50$^{cm^3}$ contains 25$^{cm^3}$ of hydrochloric acid, sp. gr. 1·16, is that of the beginning of titration of Williamson's process. In order that the effect of error due to such action upon the determination of arsenic acid may appear immediately, the thiosulphate and iodine used are expressed in terms of that acid.

These two sources of error, the one due to a liberation of iodine and the other due to decomposition of the thiosulphate, would naturally tend to overcome one another, but the completeness of such neutralization would naturally be largely a matter of chance in the varying conditions of actual analysis. The experiments of the following table, however, in which $\frac{n}{10}$ thiosulphate, to the amount of 1, 2, and 5$^{cm^3}$, was added to the liquid, 50$^{cm^3}$ and 75$^{cm^3}$, containing 25$^{cm^3}$ acid, and titrated with iodine at once, and after five minutes, were made to test the matter for the conditions of dilution at the beginning and at the end of a titration.

HCl Sp. gr. 1·16.	KI.	Volume.	$Na_2S_2O_3$ nearly $\frac{n}{10}$	in terms of H_3O_3AsO.	Iodine in terms of H_3O_3AsO, at once.	Iodine in terms of H_3O_3AsO, after 5 min.	Error in terms of H_3O_3AsO.
cm³.	gm.	cm³.	cm³.	gram.	gram.	gram.	gram.
25	2	50	1	0·0071	0·0057		−0·0014
25	2	75	1	0·0071	0·0071		0·0000
25	2	50	2	0·0141	0·0131		−0·0010
25	2	75	2	0·0141	0·0143		+0·0002
25	2	50	5	0·0353	0·0322		−0·0021
25	2	75	5	0·0353	0·0357		+0·0004
25	2	50	1	0·0071		0·0028	−0·0043
25	2	75	1	0·0071		0·0067	−0·0004
25	2	50	2	0·0141		0·0116	−0·0025
25	2	75	2	0·0141		0·0139	−0·0002
25	2	50	5	0·0353		0·0314	−0·0041
25	2	75	5	0·0353		0·0361	+0·0008

It is clear that under the conditions covered by the experiments of the two preceding tables the decomposition of the thiosulphate is likely to occur in greater or less degree, and that when the acid of sp. gr. 1·16 is not much diluted, the products of decomposition are not oxidized by the iodine completely. The latter observation is quite in harmony with the fact that sulphur dioxide bleaches iodine in strong hydrochloric acid only slowly and incompletely. In such cases dilution

favors further action of the iodine, but results obtained by titration with iodine in the acid solution diluted with an equal amount of water are unmodified by further dilution.

In the following tables are recorded actual determinations of arsenic according to Williamson's process. To each 25$^{cm^3}$ of the arseniate were added 1, 2, or 3 grams of potassium iodide and 25$^{cm^3}$ hydrochloric acid, sp. gr. 1·16. The iodine was bleached by nearly decinormal thiosulphate without addition of the starch indicator, which loses all delicacy in the presence of strong acid. The time occupied by each titration was about five minutes. The standards of the arseniate were determined by the vaporization process,* the purity of reagents employed in that process having been proved by trying the process in the estimation of a solution of arsenic acid made by oxidizing pure decinormal arsenious acid by iodine.

HCl cm^3.	KI. gram.	Volume at beginning of titration. cm^3.	Volume at end of titration. cm^3.	H_2KAsO_4 in terms of H_3O_3AsO. gram.	H_3O_3AsO found. gram.	Error. gram.
25	2	50	51	0·0062	0·0085	+0·0023
25	2	50	52	0·0125	0·0156	+0·0031
25	2	50	55	0·0312	0·0350	+0·0038
25	2	50	55	0·0624	0·0666	+0·0042
25	2	50	73	0·1559	0·1588	+0·0029
25	2	50	73	0·1559	0·1587	+0·0028
25	2	50	73	0·1559	0·1591	+0·0032
25	2	50	73	0·1559	0·1595	+0·0036
25	3	50	73	0·1559	0·1595	+0·0036
25	1	50	73	0·1559	0·1581	+0·0022
25	2	50	73	0·1559	0·1581	+0·0022
25	2	50	73	0·1559	0·1588	+0·0029

The range of error in these results is from +0·0023 gram to +0·0042 gram with a mean of +0·0031 gram—not very different from what might be expected from the effect of the interaction of the strong hydrochloric acid and the iodide alone. The counter-effect due to the decomposition of the thiosulphate is not large, yet it is probably real, as will appear in the sequel. In the following series of determinations, made with new solutions and new standards throughout, the arsenic acid was determined, first, by titrating the iodine set free by 25$^{cm^3}$ of hydrochloric acid, sp. gr. 1·16 and 3 grams potassium iodide, the solution having a total volume of 50$^{cm^3}$ at beginning and of 75$^{cm^3}$ at the end of titration and, secondly, the arsenious acid produced in the first reaction was titrated, after being neutralized with acid potassium carbonate by iodine in the presence of the starch indicator.

* Gooch and Browning, loc. cit.

H_3KAsO_4 taken, in terms of H_3O_3AsO. gram.	H_3O_3AsO found by the thiosulphate. gram.	Error. gram.	H_3O_3AsO found by titration of H_3O_3As with iodine. gram.	Error. gram.
0·1767	0·1798	+0·0031	0·1776	+0·0009
0·1767	0·1798	+0·0031	0·1777	+0·0010
0·1767	0·1795	+0·0028	0·1785	+0·0018
0·1767	0·1793	+0·0026	0·1785	+0·0018
0·1767	0·1794	+0·0027	0·1780	+0·0013
0·1767	0·1798	+0·0031	0·1785	+0·0018

The average error of the first operation is 0·0029 gram, not far from that of the previous series; the error of the second operation, the titration of the arsenious acid, amounts on the average to 0·0014 gram. In the second operation the error due to over-use of the thiosulphate by iodine set free outside the main reaction is obviously eliminated. The tetrathionate present after neutralization with acid potassium carbonate is unaffected by iodine, as we have found by titrating 25^{cm^3} $\frac{n}{10}$ iodine mixed with 25^{cm^3} hydrochloric acid, sp. gr. 1·16, by the thiosulphate, neutralizing with acid potassium carbonate,* adding starch and getting the starch blue with a single drop of $\frac{n}{10}$ iodine. The average error of this process, therefore, 0·0014, is probably due to the products of decomposition of the thiosulphate in the first operation.

From the foregoing experiments it is clear that an arbitrary correction of about 0·0030 gram must be deducted from the indications of Williamson's process of direct titration by thiosulphate, made with the greatest care under the conditions mentioned; and that a correction varying from one-half that amount (0·0015 gram) to nothing (according to the amount of arsenious acid present) when the determination is made by iodine after neutralization with acid potassium carbonate. After making these arbitrary corrections in the results of the preceding table, the individual variations fall within reasonable limits.

On the other hand, the vaporization process, in which the arseniate is reduced by boiling with sulphuric acid and potassium iodide in the manner described,† gives indications reason-

*It is worthy of note, that, as we have found by experience, it is not possible to substitute an alkaline hydroxide for the carbonate in the early stages of the process of neutralization, on account of the decomposing effect of the former reagent upon the tetrathionate. This effect is in proportion to the heating of the solution, but is never wholly absent even when ice is intermixed with the liquid and the greatest care taken to prevent a rise of temperature.

†Loc. cit.

ably regular and accurate without the application of an arbitrary correction. This process, moreover, may be shortened by restricting the volume at which heating begins so that the boiling need not be extended beyond five or six minutes. According to this slight modification, the solution of the arseniate is heated in an Erlenmeyer flask with potassium iodide to an amount about 0·5 gram in excess of the amount theoretically required and 10^{cm^3} of sulphuric acid of half strength in a total volume of between 50^{cm^3} and 75^{cm^3}. The liquid is boiled till the iodine vapors are no longer visible in the flask above the liquid, the iodine color in the still hot liquid is bleached by the cautious addition of sulphurous acid, the whole is diluted with cold water, and cooled quickly. The solution is nearly neutralized with potassium hydroxide and the neutralization is completed with acid potassium carbonate. The reduced acid is titrated with iodine after adding the starch indicator. By this procedure the results of the following table were obtained.

Volume. cm^3.	H_3O_3AsO taken. gram.	H_3O_3AsO found. gram.	Error. gram.
35	0·1559	0·1559	0·0000
35	0·1559	0·1560	+0·0001
40	0·1559	0·1559	0·0000
65	0·1559	0·1559	0·0000
50	0·2495	0·2499	+0·0004
50	0·2557	0·2449	−0·0008
60	0·3119	0·3117	−0·0002
60	0·3119	0·3120	+0·0001
75	0·3119	0·3124	+0·0005
75	0·3119	0·3132	+0·0013
75	0·3119	0·3121	+0·0002
75	0·3119	0·3115	−0·0004
75	0·3119	0·3124	+0·0005

Art. XVII.—*Further Notes on Preglacial Drainage in Michigan;* by E. H. Mudge.

The most complete study and discussion of the surface geology of Michigan that has recently been published is contained in No. 30 of the Water Supply and Irrigation Papers of the U. S. Geological Survey, under the title, "Water Resources of the Lower Peninsula of Michigan," by Alfred C. Lane, State geologist. Besides much information of economical importance, this pamphlet contains a series of very useful maps, an attempt to work out more fully than has heretofore been done the system of Preglacial drainage, and other matters of more special scientific interest. Prof. Lane has probably given more study to the records of deep wells and other similar data than any other man in the state, and concludes that the theory of Dr. Spencer, heretofore adopted by the writer, that in Preglacial times a large stream flowed across the state from west to east at about the locality of the Grand-Saginaw valley, is incorrect. He believes that the principal Preglacial stream had its rise in the vicinity of Saginaw bay, flowing west and northwest across the peninsula to the vicinity of Manistee, on the Lake Michigan shore, a route far to the north of the Grand-Saginaw valley.

This conclusion is based, first, on the fact that a limestone ridge is believed to extend clear across Saginaw bay at a level so high as to render a large drainage channel in that direction extremely improbable; second, on the condition of the rock surface in the vicinity of Manistee, which so far as known is extremely broken and uneven, characteristic of a locality well down the course of a stream rather than near its head; and third, deep borings at scattered intervals along the line find the rock-surface at lower levels than is known elsewhere in the state.

The writer has no preconceived theories which he is bound to maintain, and concedes that Prof. Lane's theory rests on coherent even if somewhat meager evidences. However, the element of speculation is necessarily large, and the problem can scarcely yet be considered definitely settled. I desire to present some new facts bearing on the question, which render it necessary to modify quite materially Prof. Lane's contour map of the rock surface (Plate VI of his pamphlet). As a matter of course, in the present state of knowledge, large areas of the rock surface being totally unknown, such a map must contain a large element of guesswork, and Prof. Lane, I am sure, will welcome any corrections of the same. His map

is constructed with contour intervals of 100 feet, the contour lines being arranged in harmony with the theory of a deep central valley in the location above indicated. The valley corresponds to the 300-foot contour (above sea level), the lines rising to the north and south. There is but a brief space to the south between the 300-foot and 400-foot contours; thence to the 500-foot contour the distance is from five to ten miles, and fifteen or twenty miles farther to the 600-foot line. The 600-foot line enters Ionia County near the northwest corner and traverses the county in a southeasterly direction, crossing Grand river a short distance east of Ionia City, at the locality of the outcrop of Carboniferous sandstone, known locally as the Ionia sandstone quarry. This outcrop in its bearing upon another problem has been described more fully in a previous paper.* It is the only outcrop in this part of the state, is located on the flat bottom of the river valley, and has an altitude of about 650 feet, or fifty feet higher than the contour line, which presumably is intended to represent the average altitude of the rock surface in this vicinity.

A comparison of this outcrop with some neighboring localities reveals some surprising irregularities. To the east the rock surface is quite unknown, but at Lyons, three miles east, a well has been sunk to a point a little below the 600-foot level, and another at Pewamo, six miles farther east, nearly to the 500-foot level, without penetrating rock. To the west, however, more definite results have been attained. In the city of Ionia, three miles down the river from the sandstone outcrop, two deep wells were put down two years ago, penetrating rock at about the 550-foot level. As Ionia is located between the 600-foot and 700-foot contour lines on the map, it is seen that the 600-foot line must be removed several miles to the southwest at this point.

But this is not all. Nine miles still farther down the valley the village of Saranac now has in process of construction a well which at last reports was down to a depth of more than 250 feet, the rock surface having been found at a depth of 248 feet. The location of the well has an elevation of about 650 feet, hence the rock surface is at about the 400-foot level. It follows that not only must the 600-foot contour line be shifted so as to include this locality, but also the 500-foot line, which appears on the map 25 miles to the north, while the 400-foot line would pass through Saranac instead of bordering the central valley 30 to 40 miles away. That is, the rock surface at Saranac is only about 100 feet above the bottom of the central valley.

* This Journal, November, 1895.

Probably the most natural conclusion to be derived from the above facts is that a branch of the main valley has its rise somewhere to the south of the Saranac. Prof. Lane's contours indicate a branch valley coming in from the south along the east line of Ionia and Montcalm Counties. As no deep borings are known along this line, it is presumed that such branch valley is simply a probability, based upon little known conditions. It would not require a very great change in the direction of this supposed branch valley to bring it in line with the Saranac boring.

It is not likely that the Saranac well indicates an east and west valley, because the rocks to the east rise rapidly, as shown by the Ionia wells and the sandstone outcrop above mentioned, while to the west in the vicinity of Grand Rapids the rock surface is above the 600-foot level. Neither is it probable that the valley opened to the south. The only other theory is that the main valley had become so extensive in Preglacial times as to include the Saranac location, but this presumes an amount of base-leveling out of harmony with the general situation. It may, therefore, be taken as at least fairly well settled that an important branch of the drainage system, probably not inferior to the eastern division, exists beneath the drift not far from the line indicated. Future borings along this line in Ionia and Montcalm Counties will be watched with interest.

Grand Rapids, Mich.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *The various forms of Sulphur.*—A paper by R. Brauns in a recent number of the *Jahrbuch für Mineralogie** discusses with much fullness the various forms assumed by sulphur on crystallizing from a state of fusion. Various new points of interest and importance are brought out, and the author concludes that there are eight modifications of sulphur to be recognized, as follows: (1) orthorhombic; (2) monoclinic-prismatic, Mitscherlich; (3) crypto-fibrous-radiated, with concentric structure, monoclinic? (No. 3 of Muthmann); (4) fibrous-radiated, monoclinic (soufre nacré of Gernez); (5) fibrous-radiated, orthorhombic; (6) triclinic; (7) monoclinic, in six-sided plates (Muthmann); (8) rhombohedral (Engel).

In addition to these he mentions, also, two forms of fluid fused sulphur and two or three forms of sulphur vapor, differing in their vapor density. The conclusion is, therefore, that sulphur can assume twelve states differing in the degree of energy characterizing them.

Another investigation on a similar subject, published just before this, is by O. Bütschli, Professor of Zoology at Heidelberg.† The author has been led, through his investigation of the various forms of microscopic structure belonging to different organisms, to extend his study also to inorganic substances. He here discusses the behavior of drops of sulphur produced from sublimation: he shows that a vaporization of the solid sulphur could be noted at 58°, and that at this temperature, as well as at the point of fusion, minute superfused drops are yielded which remain fluid for a long time, and solidify spontaneously or through pressure in the form of doubly refracting spherulites. The microscopic structure of these is given with minuteness, and a series of plates—one of them colored—shows the various forms observed.

2. *The Diurnal Variation of Atmospheric Electricity.*—For a period of seven years, from 1892 on, observations have been conducted on the summit of the Eiffel Tower in Paris, during the months from May to October, having as their object the determination of the electrical condition of the atmosphere; continuous observations have been also made at the *Bureau central* in Paris for a slightly longer period. A discussion of these by A.-B. Chauveau shows that they lead to the conclusion that there exist in our temperate regions two very different types of diurnal variation near the surface of the earth. One corresponds to the

* Beilage-Band, xiii, pp. 39–89.

† Untersuchungen über Mikrostrukturen des erstarrten Schwefels nebst Bemerkungen über Sublimation, Überschmelzung und Übersattigung des Schwefels und einiger anderer Körper. Pages 96, with 6 text figures and 4 plates. Leipzig. 1900 (Wm. Engelmann).

warm, the other to the cold season. During the summer there is a pronounced minimum in the hot hours of the day, which is more pronounced the nearer the point of observation is to the surface of the earth, and the more it is free from the influence of trees or buildings. There is another minimum in the night, the importance of which varies in an inverse direction; the existence, however, of a double daily oscillation is well marked. During the winter the afternoon minimum disappears more or less completely, while that of the night increases; there is thus a single oscillation with a maximum by day and a minimum at night; the hour of the latter corresponds to that of the second minimum of summer, about 4 P. M. Observations at other localities show very much the same phenomena.

It is concluded, in the second place, that the diurnal variation at the summit of the Eiffel Tower during the summer differs entirely from that observed simultaneously at the *Bureau central* a few hundred meters distant, but offers a close analogy in its single oscillation to the variation observed in winter. Similar results are obtained at the summit of a wooden pylon used to support anemometers at the observatory at Trappes.

The final conclusions reached are to this effect: that the influence of the soil and the maximum in summer (due, according to the suggestion of Peltier, to the water vapor emanating from the surface, and negative like that) is the cause of the perturbation in the diurnal variation; that the general law of this variation is very simple, having a maximum in the day and a minimum between 3:30 and 4:30 A. M.—*Séances Soc. Franç. de Physique*, 1899, p. 91.

3. *Lehrbuch der Photochromie* (*Photographie der natürlichen Farben*) von WILHELM ZENKER. Neu herausgegeben von Prof. Dr. B. SCHWALBE. Mit einem Bildniss des Verfassers und einer Spectraltafel. Pages 157. Braunschweig, 1900 (Fr. Vieweg u. Sohn.—This volume is for the most part a re-publication of a work by Zenker (1829–1899) issued by the author, in 1868, but thus far little known. The sketch of the author's life by G. Krech, with which the volume opens, shows that he was a remarkable man of original talents, whose contributions to science covered a wide range of subjects. Early interested in the work of E. Becquerel (1848) on color photography, he devoted much time and study to the subject, and his results are given in the volume before us. The chief point which he regarded as being established was this: that silver chloride, particularly the violet silver sub-chloride, takes the same colors as the light rays which act upon it, and shows them both by reflected and transmitted light. This result was explained physically as due to the formation of stationary light-waves which caused the separation of particles of metallic silver in the silver chloride. It will be recognized at once that this is the line in which such brilliant work has since been done by Lippmann, and the relation of the experiments and theoretical discussion of Zenker to the labors of those who have followed him is given in the closing pages of the volume (133–157) by E. Tonn.

4. *On the Joint Transmission of Direct and Alternating Currents.*—In a paper presented before the recent meeting of the American Association, Dr. FREDERICK BEDELL discussed the simultaneous transmission of direct and alternating currents by the same conductor. He shows that each current acts as though it had the whole conductor to itself and the other current were absent. Further there results a saving in weight of copper and copper losses, which saving, as shown by calculation, may amount to as much as fifty per cent.

II. GEOLOGY AND MINERALOGY.

1. *Geology of the Narragansett Basin;* by N. S. SHALER, J. B. WOODWORTH and A. F. FOERSTE. Monograph XXXIII, United States Geological Survey, pls. i–xxxi, figs. 1–30, pp. v–xx, 1–402, Washington, 1899.—The investigations reported in this Monograph were begun as early as 1865 by Professor Shaler, at first in connection with his university classes in geology. Ten years ago the completion of the work for publication as a monograph was undertaken in connection with the United States Geological Survey, and has been completed with the assistance of Mr. Foerste, working in the southern section, and Mr. Woodworth, in the northern portion of the field. The study of the construction of the basin has led to one important conclusion, which requires special notice, which may be best expressed by quoting the words of Professor Shaler: "The judgment as to the nature of the mountain-building work rests in part upon observations—in the main unpublished—which I have made in other somewhat similar basins that lie along the Atlantic coast from Newfoundland to North Carolina. The general proposition that the basins are characteristically old river-valleys which have been depressed below the sea level, filled with sediments —the sedimentation increasing the depth of the depression—and afterwards corrugated by the mountain-building forces, will derive its verification in part, if at all, from the study of other troughs of the Atlantic coast. It may, however, fairly be claimed that the facts set forth in this memoir show that this succession of actions has taken place in the Narragansett field."

Mr. J. B. Woodworth has written a report upon the northern and eastern portion of the basin (pp. 99–214). In his report the pre-Carboniferous rocks recognized are classified as follows:

Algonkian Period
- Blackstone series
  - Cumberland quartzites
  - Ashton schists
  - Smithfield limestones.

Rocks of Cambrian age are recognized in drift pebbles, but not in place in the northern basin.

The rocks of the Carboniferous system are classified under the following names: from below upward:

Pondville group	100 ft.
Millers River conglomerates	
Wamsutta group	1,000 ft.
Wamsutta conglomerates	
Attleboro sandstone	
Wamsutta slates and shales.	

These rocks are regarded as below the Coal Measures which begin with the following :

Rhode Island Coal Measures	10,000 ft.
Cranston beds	
Pawtucket shales	
Sockanasset sandstones	
Mansfield beds	
Tenmile River beds	
Seekonk sandstones	
Westville shales.	
Dighton group	1,000–1,500 ft.
Seekonk conglomerate	
Rocky Woods conglomerate.	

The classification of the rocks of the southern field is made and reported on by Mr. Foerste (pp. 223–393). His basal conglomerate and arkose are the equivalent of Mr. Woodworth's Pondville group. The Wamsutta beds are not traceable south of Providence. The Kingstown series of Dr. Foerste corresponds in part to the Mansfield, Cranston, Sockanasset and Pawtucket beds of Woodworth, and Foerste's Aquidneck shales correspond to the Westville, Seekonk and Tenmile River beds of Woodworth. The Dighton formation of the north is called Purgatory conglomerate in the southern field. It is unfortunate that the two parts of a field so small as the Narragansett Basin could not receive the same nomenclature. An insect fauna was found in the Pawtucket shales, which has already been described by Dr. S. H. Scudder. Special reference is made to this paper in the following article. The plants are also chiefly from the Pawtucket shales, and the list of species already reported in this Journal (3d series, vol. xxxvii, p. 229) were identified as equivalent to the flora of the Upper Carboniferous of Pennsylvania, by Lesquereux. W.

2. *View of the Carboniferous Fauna of the Narragansett Basin ;* by ALPHEUS S. PACKARD, Proc. Amer. Acad. Arts and Sci., vol. XXXV, No. 20, fig. 1, pp. 399–405, April, 1900.—The author having recently studied new material, collected by Mr. J. H. Clark, of Providence, from this coal field, enumerates the following animal remains at present known from the Narragansett Coal Basin :

Spirorbis carbonarius. Pawtucket plant beds.
Impression of an Annelid? Pawtucket plant bed.
Impression of a plant or worm? South Attleboro, Mass.
Sections of worm holes. One mile south of East Attleboro.
Anthracomya arenacea (Dawson) Hind.

Track of a gastropod mollusc? Pawtucket plant beds.
Protichnites narragansettensis, n. sp. Pebble, dark arenaceous shales, North Providence.
Remains of a Crustacean? Black shales, Valley Falls.
Ostrakichnites carbonarius (*Protichnites carbonarius*) Dawson. Boulder, red shale, South Attleboro.
Anthracomartus woodruffi Scudd. Pawtucket plant beds.
Mylacris packardii Scudd. Bristol plant beds.
Etoblattina, 9 species, Scudd. Pawtucket plant beds, etc.
Gerablattina scapularis Scudd. Pawtucket plant beds.
Gerablattina fraterna Scudd. Silver Spring, East Providence.
Rhapidiopsis diversipenna Scudd. Cranston plant beds.
Paralogus æschnoides Scudd. Silver Spring, East Providence.

"The presence of the Spirorbis and of the tracks of two marine Arthropods suggest that the Rhode Island plant beds, even if in general of fresh-water origin, were deposited where the sea had access to them. The presence of these marine fossils, with the fresh-water naiad, *Anthracomya arenacea*, strongly suggests that the horizon of the black shales of Providence and also of the red and greenish beds of Attleboro, Mass., belong to the same horizon as those of the South Joggins of Nova Scotia, which is Upper Carboniferous, the rocks there consisting of sandstones and dark carbonaceous shales, frequently becoming reddish. The South Joggins shales also contain the remains of Anthrapalæmon, which should be looked for in the Narragansett Coal Measures. Thus far, then, the animal remains confirm Lesquereux's reference of the dark plant-beds to the Upper Coal Measures.

These beds also appear to be higher in the series than the Middle Carboniferous Mazon Creek beds of Illinois, which contain a larger number of marine animals, viz: Belinuridæ (Euproöps, Prestwichia and Belinurus), besides Anthrapalæmon and Acanthotelson, together with the impressions of marine annelid worms." W.

3. *Geological Survey of Canada. Summary Report of the Geological Survey Department for the year* 1899; by GEORGE M. DAWSON, Deputy Head and Director, pp. 1–224, Ottawa, 1900. —The Canadian Survey was conducted with its characteristic energy during the year 1899. The finding of gold in the Yukon District, and the search for petroleum on the Saskatchewan has given these regions special importance, but activity has been shown in all parts of the country. Sixteen field parties were engaged during the summer, viz: in British Columbia, 3; Yukon District, 1; Great Slave Lake, 1; Alberta (boring operations), 1; Saskatchewan, 1; Ontario, 3; Ontario and Quebec, 1; New Brunswick, 2; Nova Scotia, 2; Ungava (East coast of Hudson Bay), 1; while several of the staff were engaged on special investigation upon collections, or materials, requiring laboratory study.

The investigations in the Yukon District, under direction of

Mr. McConnell, have been carried to considerable detail on account of the economic importance of the field. Gold is found in rich quantities in the stream-gravels, and "the product of a few of the 500-foot claims on Eldorado and Bonanza Creeks will exceed a million dollars each; while a considerable number on the same two creeks (in fact, the majority of the lower Eldorado claims and a few on Hunker Creek) will yield over half a million each, and claims running from a quarter to half a million are common on all these creeks and also on Dominion and Sulphur Creeks. Assuming a quarter of a million as the average, and that three-quarters of the claims in the district given above are rich enough to work, the total value approaches $95,000,000, a figure which is well within the mark."

The borings in Northern Alberta, in attempts to reach the petroleum-bearing strata at the base of the Cretaceous, have still failed to reach the "tar-sands," which, it is estimated, lie at a depth of about 2000 feet in the Victoria region. Only 1840 feet have been penetrated, owing to the extreme difficulties of holding the bore-hole open at great depth. The soft and incoherent character of the great mass of the overlying rocks requires casing to be carried on *pari passu* with the drilling. It is estimated that the Victoria bore-hole is down to within 250 feet of the "Tar-sands." At Athabasca Landing, the bore-hole reached to very near the top of the Tar-sands. At the Pelican River locality the Tar-sands were reached, and penetrated 87 feet before the gas and tar closed the hole and the working. It is believed that the underlying Devonian limestones are the natural source of the petroleum or maltha accumulated in the "Tar-sands."

Gold was discovered in the alluviums of Serpentine River, New Brunswick, but in small quantities. In York County, New Brunswick, Silurian fossils have been discovered, indicating the probable inclusion of Silurian rocks in folds of older Cambro-Silurian rocks which are more or less altered by metamorphism. Gold-bearing rocks were exploited in several localities in Nova Scotia. The Plant beds of Harrington River, Nova Scotia, were shown to be of Devonian age. Upper Cambrian fossils were discovered in the older Paleozoic rocks of Cape Breton Island by G. F. Matthew. Trenton fossils from Akpatok Island, Ungava Bay, already reported by Dr. Bell in this Journal (June, 1899), are referred to. Marine fossils of the Windsor series from Cumberland County, Nova Scotia, were brought to light by Dr. Ami. Discussion of the age of the Riversdale, Horton and Plant beds of St. John of New Brunswick and Nova Scotia, tend to confirm their Carboniferous affinities. The fish of McArra's Brook, Antigonish County, N. S., are correlated with the Old Red hornstones of Hereford district of England, above the passage beds, by A. Smith Woodward. The appropriation used by the Survey was a little over one hundred and eighteen thousand dollars. W.

9. *Fossil Flora of the Lower Coal Measures of Missouri;* by

DAVID WHITE, Monograph, vol. xxxvii, U. S. Geological Survey, pp. 1–467, plates i–lxxiii, 1899.—The material upon which this monograph is based was collected from the Coal Measures of Henry County, Missouri, by Dr. J. H. Britts of Clinton, Mo., and by Mr. Gilbert VanIngen and Dr. W. P. Jenney of the U. S. Geological Survey. The whole flora has been exhaustively studied, many new species described, and the old species subjected to careful criticism and revision.

Comparison of the flora with those of other regions in the United States and other countries has led to the following determinations of correlation of horizon for the Missouri flora, viz: "The Lower Coal Measures of Missouri, as represented by the coals of Henry County, were laid down soon after the Morris coal of Illinois, though probably earlier than the Upper Kittanning of western Pennsylvania, or very likely about the time of the formation of the D coal in the Northern Anthracite field."

In the European sections, close affinity is found between this flora and that of the zone of Bully-Grenay in the Valenciennes Basin, but as the author remarks, the fauna is perhaps in a measure transitional, "while it is probably contemporaneous with a portion at least of the upper zone of the Valenciennes Basin, as presented in the basins of Commentry or the Saar, . . . it may represent a slight paleontological transgression on the Stephanian ('Houiller supérieur')." It is represented in Silesia and Bohemia by the Schatzlar and Radnitzer Schichten, and corresponds with the "Transition Series" of Great Britain. W.

5. *La Face de la Terre* (*Das Antlitz der Erde*) par ED. SUESS, translated by EMMANUEL DE MARGERIE, vol. ii, plts. 1 and 2, figs. 1–128, pp. 1–878. Paris, 1900 (Armand Colin & Cie).—Those familiar with the original edition of Professor Suess' Antlitz der Erde will not need to be reminded of the extreme value of the French edition, the second volume of which has recently appeared. It furnishes a store-house of information regarding the structure of the land surfaces and the geological structure of the earth not met with elsewhere, except as distributed in a very large number of publications. The first volume has already been noticed in this Journal (see vol. v, p. 152). In the translation, M. de Margerie has had the assistance of MM. Bernard, Depéret, Kilian, Poirault, Six and Zimmerman. The translations are admirably made, and the editors have added 85 new cuts to the French edition. These are many of them charts, and add much to the value of the volume. The translators have also added, in foot-notes, a large number of new references to literature, bringing the bibliography up to 1899, which will increase the value of the book for investigators. The present volume discusses the oceans and the geological conditions of the land and ocean surfaces during the Paleozoic, the Mesozoic, the Tertiary; and in the latter part of the volume, a number of chapters are devoted to special subjects, such as the Temple of Sérapis, Baltic and North Seas, the Mediterranean during historic period, etc. W.

6. *The Gneisses, Gabbro-schists and associated Rocks of Southwestern Minnesota;* by C. W. HALL. (Bull. U. S. Geol. Surv. No. 157, 1899, pp. 160, pl. xxvii.)—The territory from which the material described in this paper was gathered embraces the valley of the Minnesota River and the southwest corner of the State of that name wherever gneisses are found. In the 120 miles of the river valley there project through its flood plain many exposures of gneisses, gabbro-schists, diorites and diabasic effusives. They often fill the entire valley one to two miles wide, rising in a profusion of knobs and hills 50 to 100 feet above the river. These exposures of crystalline rocks are described by districts, with maps of each district, on which they are located. Their geological relations are discussed and an account of their petrography, which appears to be that of well known types, is given with the addition of numerous colored plates. L. V. P.

7. *Brief Notices of some recently described Minerals.*—MÜLLERITE is a hydrosilicate of ferric iron described by Zambonini from Nontron, France, which is the original locality of the related nontronite (chloropal). It occurs in opaque incrusting masses of a yellowish green color; it is quite soft and has a specific gravity of 1·97. The mean of three analyses gave:

SiO_2	Fe_2O_3	Al_2O_3	MnO	MgO	H_2O
48·82	35·88	4·30	0·63	0·35	9·66=99·64

This corresponds to the formula $Fe_2O_3.3SiO_2+2H_2O$, which differs from the accepted composition of nontronite only in having three molecules less water.—*Zeitschr. Kryst.* xxxii, 157.

MELITE is a name given by the same author (l. c., p. 161) to partially investigated hydrosilicate of alumina and ferric iron known from a single specimen, labeled "Allophane, Saalfeld, Thuringia." It occurs in imperfect crystals (?) and stalactitic forms of bluish-brown color and opaque; the hardness is 3 and the specific gravity 2·18. An analysis gave: SiO_2 14·97, Al_2O_3 35·24, Fe_2O_3 14·70, CaO 0·78, H_2O 33·75=99·64.

ROBELLAZITE. Briefly mentioned by M. Cumenge as occurring with the carnotite in Colorado. A partial chemical examination by M. Debierne, it is stated, shows that it contains considerable vanadium and also niobium, tantalum and tungsten with alumina, iron and manganese as bases.—*Bull. Soc. Min.*, xxiii, 17, 1900.

CUPRO-GOSLARITE. A cupriferous variety of goslarite described by A. F. Rogers as forming a light greenish blue incrustation in an abandoned zinc mine at Galena, Kansas. An analysis gave: SO_3 [27·02], ZnO 23·83, CuO 6·68, FeO 0·13, H_2O 41·76, insol. 0·58=100.—*Kansas Univ. Q.*, viii, No. 2.

CUBOSILICITE is a name given by Bombicci to the bright blue form of silica in cubic crystals occurring at Tresztyan, Transylvania, and ordinarily regarded as pseudomorphous chalcedony, perhaps after fluorite. This he classifies as a definite form of silica (pseudo-isometric, mimetic) related to melanophlogite, sulfuricine and cristobalite.—*Mem. Accad. Bologna*, viii.

III. Miscellaneous Scientific Intelligence.

1. *American Association for the Advancement of Science—New York Meeting.*—The forty-ninth meeting of the American Association was held in New York City, during the week from June 25 to 30. The President of the meeting was Professor R. S. Woodward. The attendance was satisfactorily large, though perhaps not so numerous as the time and place of meeting might have seemed to promise; the total registration was about 450. In scientific spirit, however, the occasion was highly successful, the number of the papers presented being large and their character and interest above the average. The sessions of the Association were held in the buildings of Columbia University and the efforts of the officers of this institution and of those of the American Museum of Natural History contributed largely to the general success of the meeting.

The retiring President, Mr. G. K. Gilbert, delivered on Tuesday evening an admirable address upon the subject "Rhythms and Geologic Time." Other addresses were delivered by the Vice Presidents of several of the sections, as follows: Section A, on the teaching of Astronomy in the United States, by Asaph Hall, Jr.; Section B, on the Cathode Rays and some related phenomena, by Ernest Merritt; Section C, on the eighth group of the Periodic System and some of its problems, by Jas. Lewis Howe; Section D, on Some Twentieth Century problems, by William Trelease; Section E, on Precambrian sediments in the Adirondacks, by J. F. Kemp. These addresses are published in full in Science (issues of June 29 and following). In addition to the work before the different sections, fifteen affiliated societies had meetings in connection with the Association, and this fact added much to the scientific interest of the occasion.

The place selected for the meeting of 1901 is Denver, Colorado; the meeting will begin on Monday, August 26th. Pittsburg was recommended for the meeting of 1902. The officers elected for next year are as follows:

President: Charles S. Minot, Harvard Medical School.

Vice-Presidents: Section A, James McMahon, Cornell University; Section B, D. D. Brace, University of Nebraska; Section C, John H. Long, Northwestern University; Section D, H. S. Jacoby, Cornell University; Section E, C. R. Van Hise, University of Wisconsin; Section F, D. S. Jordan, Leland Stanford University; Section G, B. T. Galloway, U. S. Department of Agriculture, Washington; Section H, J. W. Fewkes, Bureau of Ethnology, Washington; Section I, John Hyde, Department of Agriculture, Washington.

Permanent Secretary, L. O. Howard of Washington; General Secretary, William Hallock, Columbia University; Treasurer, R. S. Woodward, Columbia University.

2. *British Association for the Advancement of Science.*—The coming meeting of the British Association will be held at Brad-

ford, England, commencing Sept. 5. The President is Professor Sir William Turner of Edinburgh.

3. *Catalogues of the Collections in the British Museum of Natural History.*—Recent issues of this series include the following:

The Cretaceous Bryozoa, volume i, pp. xiv, 457 with 17 plates; by J. W. GREGORY, London, 1899. This follows an earlier work (1896) on the Jurassic Bryozoa, in which there was given an Introduction upon the structure and affinities of the group. The second volume upon the Cretaceous Bryozoa is promised for the present year.

Catalogue of the Arctiadæ (Nolinæ, Lithosianæ); by Sir GEORGE F. HAMPSON. Pp. xx, 589; plates xviii–xxxv. London, 1900. This is the second of the volumes devoted to the Lepidoptera Phalenæ.

4. *The Norwegian North-Atlantic Expedition, 1876–1878.*—The following publications have recently been issued, containing the results of the further study of the zoological collections made by the Norwegian North Atlantic expedition.

XXV, Thalamophora by Hans Kiær, with 1 plate and 1 map.

XXVI, Hydroida by Kristine Bonnevie, with 3 figures, 8 plates and 1 map.

XXVII, Polyzoa by O. Nordgaard, with 1 plate and 1 map.

5. *The Grammar of Science*; by KARL PEARSON, 2d ed. revised and enlarged, pp. 1–548, figs. 1–33 (Adam and Charles Black, London; Macmillan Company, New York), 1900.—This book illustrates the undoubtedly strong trend of opinion among leaders of scientific thought toward some form of idealism. The inadequacy of the cruder forms of materialism to satisfy the questioning of the thinking mind has led men to look inward to the form of their conceptions of phenomena, in order to ascertain the relation these phenomena bear to each other.

The following passage expresses tersely the author's purpose: "The object of the present work is to insist . . . that science is in reality a classification and analysis of the contents of the mind; and the scientific method consists in drawing just comparisons and inferences from the stored impresses of past sense-impressions, and from the conceptions based upon them. Not till the immediate sense-impression has reached the level of a conception, or at least a perception, does it become material for science. In truth, the field of science is much more consciousness than an external world. In thus vindicating for science its mission as interpreter of conceptions rather than as investigator of a 'natural law' ruling an 'external world of material,' I must remind the reader that science still considers the whole contents of the mind to be ultimately based on sense-impressions" (p. 52). The volume is full of keen observations and suggestions. The chief additions made in this edition are the chapters discussing the biological conceptions of science. W.